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CAN/UK SAT-DIVES 1 & 2/85

OPERATIONS SUMMARY REPORT

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ABSTRACT

The Canadian Experimental Diving Division, in conjunction with the Admiralty Research Establishment, Physiological Laboratory agreed to conduct 2 Helium/Oxygen (HeO_2) Saturation Dives to depths of 100 msw and 360 msw in the Diving Research Facility (DRF). These dives were conducted under the auspices of the Canada/United Kingdom Memorandum of Understanding (CAN/UK MOU) on Human Undersea Program and they were formally designated CAN/UK SAT-DIVE 1/85 and CAN/UK SAT-DIVE 2/85.

The aim of SAT-DIVE 1/85 was basically training while the aim of SAT-DIVE 2/85 was to complete a series of equipment performance evaluations enroute to and while at 360 msw. These evaluations looked at 3 types of equipment; a divers gas recirculating system, different types of diver thermal protection suits, and diver monitoring equipment.

SAT-DIVE 2/85 consisted of 4 days of compression, 8 days at 360 msw and sixteen days of decompression. Over the period of the dive all objectives were successfully met.

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LIST OF ABBREVIATIONS

ARE(PL) ..... Admiralty Research Establishment (Physiological Laboratory)

BIBS ..... Built-in-Breathing System

CEDD ..... Canadian Experimental Diving Division

D/CEDD ..... Director/Canadian Experimental Diving Division
DC ..... Dive Chamber
DEL ..... Diving Electronics Laboratory
DER ..... Diving Engineering Requirements
DGUW ..... Director General Underwater Weapons
DMO ..... Diving Medical Officer
DOS ..... Diving Operations Section
DRF ..... Diving Research Facility
DWO ..... Diving Watch Officer

ECG ..... Electrocardiograph
ECL ..... Environmental Control Loop
ECU ..... Environmental Conditioning Unit
EEG ..... Electroencephalograph
EPS ..... Emergency Procedures

FCO ..... Finn Christian Olsen

GSOL ..... Gas Services Offshore Limited

HE ..... Hyperbaric Engineer
HPNS ..... High Pressure Neurological Syndrome
HYPOPS ..... Hyperbaric Operations Section

INM ..... Institute of Naval Medicine

LC ..... Living Chamber

MOU ..... Memorandum of Understanding
MSW ..... Metres of Seawater
MTF ..... Mobile Test Facility

NDMC ..... National Defence Medical Centre
NGL ..... Normalair Garrett Limited
NRV ..... Non-return Valve
NUTEC ..... Norwegian Underwater Technology Centre

RN ..... Royal Navy
RNTSO ..... Royal Navy Trials Safety Officer

SAT-DIVE ..... Saturation Dive
SDHU ..... Submersible Divers Heating Unit
SDMO ..... Submarine and Diving Medical Officer
SMDC ..... Supervisors Medical Officers Console
SOHM ..... Staff Officer Hyperbaric Medicine
SOPS ..... Standard Operating Procedures

TC ..... Transfer Chamber
TSD ..... Technical Services Division

SECTION 1

GENERAL AND ADMINISTRATION

1.1 INTRODUCTION

The Canadian Experimental Diving Division (CEDD) in conjunction with the Admiralty Research Establishment, Physiological Laboratory (ARE(PL)) in Alverstoke Hants, agreed to conduct 2 Helium/Oxygen (HeO_2) Saturation Dives to depths of 100 msw and 360 msw in the Diving Research Facility (DRF). These dives were conducted under the auspices of the Canada/United Kingdom Memorandum of Understanding (CAN/UK MOU) on Human Undersea Program and they were formally designated CAN/UK SAT-DIVE 1/85 and CAN/UK SAT-DIVE 2/85. This report summarizes the requirements and preparations for the dives and the operational aspects involved in the running of the dives. As such, it is intended to serve as a guide to the conduct of an operation of this magnitude and it should be read in conjunction with the other dive reports as shown in Table 1 to get a complete appreciation of the dives.

1.2 AIM

The aim of SAT-DIVE 1/85 was to train the subjects, operators, and scientific personnel in the techniques and procedures required for SAT-DIVE 2/85. From this point, the text of this report will deal primarily with SAT-DIVE 2/85.

The aim of SAT-DIVE 2/85 was to complete a series of equipment performance evaluations enroute to and while at 360 msw.

1.3 OBJECTIVES

The specific objectives of SAT-DIVE 2/85 were:

a. to conduct a series of equipment evaluations of the Gas Services Offshore Limited (GSOL) Gasmizer System at various depths down to and including 360 msw;

b. to conduct additional equipment evaluations at 360m on the following equipment:

   (1) Heliox 18B (Ultraflow 500);
   (2) Diving Systems International Open-Circuit Hotwater Suit;
   (3) Finn Christian Olsen Open Circuit Hotwater Suit;
   (4) Divematics Closed Circuit Hotwater Suit System; and
   (5) Normalair Garrett (NGL) Dive Monitor.

c. to conduct an evaluation of the NGL Patient Monitor during decompression;

d. to study the effect of the proposed compression rate and a pO_2 of 0.5 Bar on High Pressure Neurological Syndrome; and

e. to evaluate the decompression procedures in use for this dive.

1.4 COMMAND AND CONTROL

The overall command and control of SAT-DIVE 2/85 rested with the D/CEDD.

The RNTSO was appointed to be responsible for the safe conduct of all trials.

The Duty DMO was responsible for the medical safety of the dive subjects.

Deviations from the approved Dive Protocol were only permitted for diver and/or equipment safety by the DWO with the advice of the DMO or the RNTSO.

Changes to the Dive Protocol could be recommended by the DCIEM SOHM, the RNTSO, and the Head DOS. They must have been approved by D/CEDD and the independant Medical Officer who for this dive was SOHM. The latter was responsible for obtaining the informed and recorded consent of the subjects for the approved changes.

Within the abort criteria, the person designated as "Scientific" for each test could request the Team Leader, the dive test subjects or the Chamber operations personnel to adjust hot water flow, hot water temperature or any other parameters as necessary to maximize the value of the scientific data being collected. Every effort was made to identify the required adjustments during the pre-test briefing to minimize unexpected changes during the test. The overall organizational structure is shown in Figure 1.

1.5 DIVE SUPPORT

Medical support was provided by SOHM, a CF Submarine and Diving Medical Officer (SDMO), and an RN DMO from Director General Underwater Weapons (Naval) (DGUW(N)).

Operations and Engineering support was provided by CEDD staff and DGUW while Scientific and Diver monitoring support was provided by CEDD staff and Biosciences Division personnel.

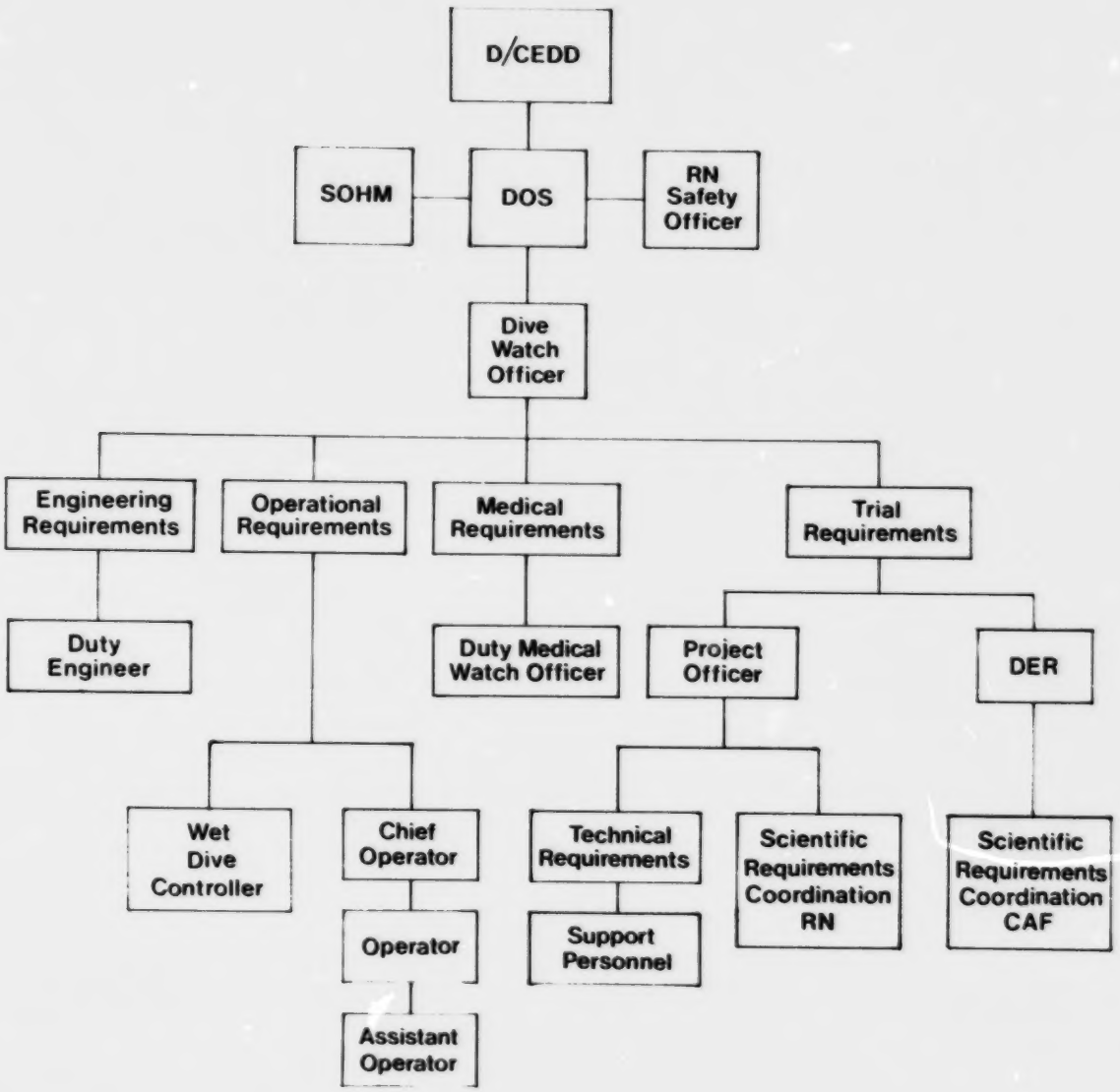

D/CEDD
SOHM
DOS
RN Safety Officer
Dive Watch Officer
Engineering Requirements
Operational Requirements
Medical Requirements
Trial Requirements
Duty Engineer
Duty Medical Watch Officer
Project Officer
DER
Wet Dive Controller
Chief Operator
Technical Requirements
Scientific Requirements Coordination RN
Scientific Requirements Coordination CAF
Operator
Support Personnel
Assistant Operator

Figure 1

Logistic support in the form of transportation, hot meals and cafeteria services for personnel on watch and the dive subjects was initially split between CFB Toronto and DCIEM. After the first week, however, it became necessary for DCIEM to assume the responsibility for the meals and watch cafeteria services as the logistics involved in working through CFB Toronto was unacceptable.

1.6 POST-DIVE MEETING

Post-dive meetings to discuss all aspects of the dive were held for the scientific personnel after completion of the bottom phase and for the operators and dive subjects after the dive surfaced.

1.7 DIVE SUMMARY

The preparations and the conduct of SAT-DIVE 2/85 involved a great many complex factors. These necessitated a major pre-dive work-load in the areas of training and logistical support, plus a vital training workup Saturation Dive to 100 msw (SAT-DIVE 1/85).

SAT-DIVE 2/85 consisted of:

a. 4 days of compression with stops at 50 msw, 120 msw, 250 msw, and 320 msw to conduct equipment trials;

b. 8 days at 360 msw to conduct trials; and

c. sixteen days of decompression.

Over the course of the dive, all the objectives of the dive were successfully met with the exception of the Divematics Suit evaluation which could not be completed due to problems identified with the suit.

1.8 DIVE REPORTS

The series of reports shown in Table 1 have been completed by the agencies and lead authors indicated to cover the total results from SAT-DIVE 2/85.

TABLE 1

SAT-DIVE'S 1/85, 2/85

SUMMARY OF REPORTS

1. **TRIAL OFFICERS REPORT**

Contents: A synopsis report covering the RN preparations, a summary of the trials, the results and recommendations to DGUW(N).

Lead Author: LCdr J.T. Hewitt

Agency: DGUW(N)
Ministry of Defence
Procurement Executive
Portland, Dorset
DIS 2JS
Weymouth, UK
(0305) 776376

2. **CAN/UK SAT-DIVES 1/85 AND 2/85 - OPERATIONS SUMMARY**

Contents: A summary of the operational requirements, preparations, and conduct of the dives and the trials.

Lead Author: LCdr B.A. Hobson

Agency: DCIEM
1133 Sheppard Avenue West
P.O. Box 2000
Downsview, Ontario
M3M 3B9
(416) 635-2080

3. **BREATHING APPARATUS TEST RESULTS**

Contents: A report on the conduct and results of the Breathing Apparatus trials.

Lead Author: Mr. D.J. Eaton

Agency: DCIEM
(416) 635-2086

TABLE 1

(Continued)

4. **THERMAL STUDY**

Contents: A report on the conduct and results of the thermal trials.

Lead Author: Mr. T. Romet

Agency: DCIEM
(416) 635-2122

5. **HPNS STUDY**

Contents: A report on the conduct and results of the HPNS testing.

Lead Author: Dr. R. Vaernes

Agency: NUTEC
Gravdalsveign
Laksevag
225-5034 Yrte
Bergen, Norway
47-5-261601

6. **DIVER/PATIENT MONITORS**

Contents: A report on the conduct and results of the diver and patient monitor trials.

Lead Author: Dr. G. Brooks

Agency: DGUW
Medical Applications Officer

7. **SCOTT BIBS MASK UNMANNED EVALUATION**

Contents: A report on the conduct and results of an unmanned evaluation of the Scott BIBS mask.

Lead Author: Mr. D. Eaton

Agency: DCIEM
(416) 635-2086

1.9 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

a. Operational

(1) Operator training was unnecessarily long and frustrating due to the method used and the numbers of personnel requiring training (Ref Section 2, Article 2.5).

Recommendation: The required levels of training should be identified early and a dedicated period established to accomplish this training.

(2) The training SAT-DIVE 1/85 was invaluable in identifying problem areas and solidifying training and procedures (Ref Section 2, Article 2.9).

Recommendation: Consideration should be given to a workup dive prior to any major dive.

(3) A 1 in 3 watch rotation for operaors is too restrictive and a 1 in 4 rotation with daily watch change is too unstable (Ref Section 2, Article 2.9 & Section 6, Article 6.7).

Recommendation: If possible, establish a 1 in 4 watch rotation with each group standing 3 days in the same watch period before rotating.

(4) The pre-dive training weeks were essential, however, insufficient weighting was given to previous subject familiarity with equipment thus, too much time was allocated to equipment familiarization and not enough to watch/operations team cohesiveness (Ref Section 2, Articles 2.8 & 2.12).

Recommendation: An appropriate balance must be maintained between these factors.

(5) The Sybron Taylor O_2 Analyzer was extremely accurate compared to the daily gas chromatograph analysis and it remained reliable throughout the dive (Ref Section 6, Articles 6.8 & 6.9).

(6) The O_2 controllers worked well once they had been setup to match the Sybron Taylor (Ref Section 6, Article 6.8).

(7) Humidity in the chamber was difficult to control over the dive (Ref Section 6, Article 6.9).

Recommendation: Investigate optimum Environmental Control Loop (ECL) system setup to remove humidity.

(8) The ECL's had difficulty controlling the CO_2 due to possible flow restriction and inadequate bed moisture (Ref Section 6, Article 6.9).

Recommendation: Investigate possible solutions for the ECL system.

(9) The Scott Built-in-Breathing System (BIBS) masks in the DRF were incapable of handling the gas delivery requirements of the moderately working diver beyond 50 msw (Ref Section 6, Article 6.12).

Recommendation: This information be published with a copy going to Scott Limited. For any immediate requirements, the AGA mask setup will suffice. For the longer term, the results of the Norwegian Underwater Technology Centre (NUTEC) BIBS mask test will be monitored.

(10) Problems arose concerning the feeding of the subjects and the watches (Ref Section 2, Article 2.12).

Recommendation: A catering company be used for any future dives.

b. **Engineering**

(1) The approach of providing interface penetration details and required hose lengths to the test equipment manufacturers and having them provide the connections was extremely successful (Ref Section 3, Article 3.2).

Recommendation: For any future dives, details of our fittings be provided to the equipment manufacturers and they be tasked to provide all interface connectors.

(2) Pre-setup visits by the manufacturers of the equipment being trialed were very successful (Ref Section 3, Article 3.2).

Recommendation: All manufacturers wishing equipment tested by required to visit DCIEM early on in the planning process.

(3) A straight 1 in 3 engineering watch is very tiring over a twenty-eight day dive (Ref Section 6, Article 6.7).

Recommendation: Either augment the watch by 1 or look at twelve hour on call in division shifts with work being done as required.

c. **Scientific**

(1) The flexibility built into the protocol to allow the scientific support side to make minor adjustments to procedures during a trial proved to be valuable when not overdone (Ref Section 4, Article 4.4).

Recommendation: An agreement to allow this flexibility be made part of all subsequent tests. There must be vigilence, however, to prevent abuse of this arrangement.

(2) The setup of the scientific side into cells with a designated "Scientific" spokesman for each experiment worked well (Ref Section 4, Article 4.4).

Recommendation: On all large scale experiments this setup should be established to control the direction of the experiment.

d. **Medical**

(1) No major medical problems occurred during SAT-DIVE 1/85 and SAT-DIVE 2/85 which can be partly attributed to preventative medicine and diver selection. As well as ear prophylaxis, antifungal and antibacterial skin preparations proved effective (Ref Section 6, Article 6.30).

Recommendation: Buffered Acetic Acid drops (VOSOL), antifungal and antibacterial skin preparations remain standard for routine prophylaxis during saturation dives.

(2) Even with the long compression to 360 metres, HPNS monitoring suggests that the divers suffered mild HPNS (Ref Section 6, Article 6.29).

Recommendation: Modification of the compression profile required to reach 360 msw at the fastest rate compatable with minimal HPNS

be investigated by continued co-operation with NH(OTP).

(3) Thermal balance for wet divers is difficult to maintain deeper than 100 metres using current heating methods. These dives should be supported by thermal monitoring (Ref Section 6, Article 6.28).

Recommendation: Diver monitoring for thermal balance deeper than 100 msw should be used routinely.

(4) The decompression profile used for SAT-DIVE 2/85 proved safe but could probably be improved by an increase in rate from 360 metres to 270 metres coupled with a decrease in the 1.5 metres/hour rate before 100 metres is reached. Night stops were essential for diver comfort and may have prevented decompression sickness (Ref Section 6, Article 6.31).

Recommendation: The decompression schedule from 360 msw be investigated for improvement in continued co-operation with NH(OTP).

(5) Computer assisted diagnosis is a useful adjunct to the medical support of deep dives where the patient cannot be examined directly by a Medical Officer (Ref Section 6, Article 6.30).

Recommendation: Computer assisted diagnosis be made available as a routine support item for deep dives.

SECTION 2

OPERATIONAL PRE-DIVE ARRANGEMENTS

GENERAL

2.1 Two major operational areas were specifically addressed prior to SAT-DIVE 2/85, logistics and training. The training requirement was the larger requirement and it will be dealt with first.

TRAINING

2.2 Using the already established manual "EDU Requirements for Hyperbaric Operators" as the basis for qualification levels, it was decided that these requirements needed to be expanded for Saturation Diving as follows:

a. **Assistant Operators**

Qualification on packages as detailed in the manual plus working familiarity with remaining areas; and

b. **Operators**

Full qualification on all system packages.

In addition, the following areas were also addressed:

a. saturation theory and practices;
b. watch training; and
c. ops/scientific/subject team training.

2.3 Finally, a ten day 100m Saturation Dive (SAT-DIVE 1/85) was conducted involving all the operational, medical, and scientific personnel to solidify the training and to trial the procedures and techniques to be used on the SAT-DIVE 2/85.

FACILITY OPERATOR TRAINING

2.4 Twelve personnel were progressed through this training program. Training started before the 100m SAT-DIVE, continued over the ten day SAT-DIVE, between the dives, and during SAT-DIVE 2/85. At the end of SAT-DIVE 2/85, the following levels had been achieved:

a. 4 personnel qualified as Assistant Operator and all four were ready to attempt the operator qualifying board by the end of the dive;

b. 2 personnel qualified as Assistant Operator and then went on to qualify as Operators;

c. 4 personnel qualified as Operators from Assistant Operator; and

d. 2 personnel qualified as Chief Operators from Operator.

2.5 This training was left to the individuals to progress at their own pace once an initial series of systems lectures were conducted. This led to a continuous training drain on the HypOps personnel which hindered their accomplishing their tasks in other areas. It also became frustrating for all involved when the other requirements started to demand all the available time. For future reference, the training requirements should be defined and a dedicated period set aside to accomplish this requirement.

SATURATION THEORY AND PRACTICE

2.6 A 2 day short course was conducted in accordance with the schedule at Figure 2. This course was intended to acquaint division operations personnel with the theories, operational, and medical procedures common to Saturation Diving.

WATCH TRAINING

2.7 This training was incorporated with the Ops Team Training requirements covered below. The purpose of this training was to:

a. instill the beginnings of watch cohesiveness; and
b. practice and learn the facility emergency procedures.

This training was short and generally just gave cursory coverage. This training was solidified during the 100m SAT-DIVE.

OPS/SCIENTIFIC/SUBJECT/TEAM TRAINING

2.8 This training was conducted in accordance with the schedule shown in Figure 3. The purpose was to develop:

a. subject familiarity with the equipment to be used and the test equipment and procedures; and

b. the operational/scientific routines and procedures.

Generally, the timing was about right except for the first 2 days when the subjects progressed through the medical and scientific requirements faster than anticipated. A short course on hyperbaric operations as conducted at EDU would have benefitted the in-houe and foreign scientific and medical personnel. As well, more emphasis should have been placed on all the participating scientific and medical staff attending the full week. A few of the key personnel arrived mid-week which caused some problems.

SATURATION DIVING THEORY AND PRACTICE

TIME	DAY 1	DAY 2
0830	Introduction Saturation Theory	Protocol Review
0905	Saturation Diving Requirements	
	COFFEE BREAK	COFFEE BREAK
1015	Dive Abort Tables Decompression Schedules	Dive Schedule Time Table
1100	Medical Problems and Hygiene	CEDD Requirements
	LUNCH	LUNCH
1315	DCS Treatment Procedures	
1400	Dive Recording Logs	
	COFFEE BREAK	COFFEE BREAK
1515	DRF Operating Procedures	
	DRF Operating Procedures	

FIGURE 2

COURSE: SAT-DIVE 1-85 PRE-DIVE TRAINING

WEEK#	MON	TUE	WED	THU	FRI
0800	PT - Dive subjects	PT- all dive subjects	PT - all dive subjects Watch B DRF Flashup	PT - all dive subjects Watch A DRF Flashup	PT - all dive subjects Watch C DRF Flashup
0900	Welcome Address				
0915	Doppler, ECG - Subjects Watch A - DRF Watch SOPs & EPs	Doppler, ECG - Subjects Watch A - DRF Watch SOPs & EPs	Dry Bike Test Surface Subjects Watch A - Assist/ Observe	GSOL Test C - 30' Subjects Watch B Assist monitoring - manned	GSOL Test C - 30' Subjects Watch A Assist monitoring- manned
	COFFEE BREAK	COFFEE BREAK	COFFEE BREAK	COFFEE BREAK	COFFEE BREAK
1030	Thermal Famil Subjects Watch B - DRF Watch SOPs & EPs	Thermal Famil Subjects Watch B - DRF SOP & EPs	GSOL Test C - surface Main System Test Subjects Watch A - Assist/Observe	Standby Diver's Test 30' Subjects	GSOL Test D - 30' Subjects Monitoring- manned
1115	All subjects - DRF Famil Watch C - DRF Watch SOPs & EPs	Subjects GSOL System Famil & Setup Watch C - DRF SOPs & EPs	GSOL Test D - surface Emergency System Test Subjects DRF EPs Drill	DRF - EPs Drill 30'	DRF - EPs Drill 30'
	LUNCH	LUNCH	LUNCH	LUNCH	LUNCH
1315	SOHM - briefing Subjects Consent Forms	GSOL Famil & Setup	Dry Bike Test-surface Subjects Watch C Assist/Observe	GSOL Test C-30' Subjects Watch C Assist Monitoring-manned	GSOL Test C -30' Subjects Watch B Assist Monitoring-manned
	Subjects - DRF Emergency Procedures	GSOL Famil & Setup	GSOL Test C - surface Main System Test Subjects Watch C-Assist/Observe	Standby Diver's Test 30' Subjects	Secure, clean repair equipment Start DRF cleaning Doppler refresher Subjects
	COFFEE BREAK	COFFEE BREAK	COFFEE BREAK	COFFEE BREAK	COFFEE BREAK
1500	GSOL System/Helmet Monitoring Famil - Subjects	GSOL Famil & Setup	GSOL Test D - surface Emergency System Test Subjects	DRF EPs Drill - 30'	Secure, clean repair equipment Start DRF cleaning
	GSOL System/Helmet Famil - Subjects	GSOL Famil & Setup	DRF EPs Drill	Subject Pre-Dive Medical Screening SOHM	Secure, clean repair equipment Start DRF cleaning

FIGURE 3

SAT-DIVE 1/85

2.9 This dive to 100 msw followed the schedule shown at Figure 4 and all attempts were made to simulate the conditions and criteria required for SAT-DIVE 2/85. In addition, a number of equipment trials were conducted during this dive.

The equipment tested was the Gasmizer and the Diving Systems International (DSI) non-return valve (NRV) suit. There was a total of 8 equipment trial periods during the dive with 7 successful and 1 aborted. This trial was retrieved during the time alloted for missed experiments. All the data gathered in testing the Gasmizer system was useful. Data gained by using the DSI suit showed that the splitter block and valve arrangement was unsatisfactory, and modifications were made to the splitter block before SAT-DIVE 2/85. Secondly, indications at this depth were that the DSI-manufactured latex shroud was very efficient and hot water requirements would be less than originally thought.

A straight 1 in 3 watch rotation was employed for SAT-DIVE 1/85. This was satisfactory for the short ten day period but personnel began to tire towards the end and the assigning of the personnel to the same watch for the entire period led to increased boredom for the night watches. The training provided by SAT-DIVE 1/85 was invaluable in identifying problem areas and to solidify procedures. A similar approach should be considered prior to any such major dive.

SAT-DIVE 2/85 PRE-DIVE TRAINING

2.10 A week of training was conducted prior to the dive (Figure 5). This time the subjects, scientific, and operations personnel were familiar with the bulk of the equipment and procedures. The major purpose therefore, was to develop familiarity with the additional equipment to be tested plus incorporating the lessons learned from SAT-DIVE 1/85. This period proved to be longer than required as the experience acquired from the first dive was greater than anticipated.

DIVE DAY #	TIME	DEPTH (metres)	EVENT
1	2000	Surface	Start Dive; press to 50 metres
	2200	50m	Arrive 50 metres
	2245	50m	Lights out
2	0630	50m	Commence daily routine
	1600	50m	Leave 50 metres
	1800	100m	Arrive 100 metres
3	0630	100m	Commence daily routine
4	0630	100m	Commence daily routine
5	0630	100m	Commence daily routine
	2000	100m	Commence decompression
	2000	100m	Leave 100 metres
	2005	95m	Arrive 95m
6	0100	95m	Leave
	0105	90m	Arrive
	0600	90m	Leave
	0605	85m	Arrive
	1100	85m	Leave
	1105	80m	Arrive
	1600	80m	Leave
	1605	75m	Arrive
	2100	75m	Leave
	2105	70m	Arrive
7	0200	70m	Leave
	0205	65m	Arrive
	0700	65m	Leave
	0705	60m	Arrive
	1200	60m	Leave
	1205	55m	Arrive
	1700	55m	Leave
	1705	50m	Arrive
	2200	50m	Leave
	2205	45m	Arrive

FIGURE 4

SAT-DIVE 1/85 PROFILE

DIVE DAY #	TIME	DEPTH (metres)	EVENT
8	0400	45m	Leave
	0405	40m	Arrive
	1000	40m	Leave
	1005	35m	Arrive
	1600	35m	Leave
	1605	30m	Arrive
	2200	30m	Leave
	2205	25m	Arrive
9	0500	25m	Leave
	0505	20m	Arrive
	1200	20m	Leave
	1205	15m	Arrive
	1900	15m	Leave
	1905	10m	Arrive
10	0200	10m	Leave
	0205	5m	Arrive
	0900	5m	Leave
	0905	0m	Arrive at surface

FIGURE 4

(continued)

SAT-DIVE 1/85 PROFILE

PRE-DIVE TRAINING PROGRAM / SAT-DIVE 2-85

DATES - From 17 Jun 85 TO 21 Jun 85

WEEK	MON	TUE	WED	THU	FRI
0800 0900	PT - HPNS tests Dive subjects	PT & HPNS tests	Dive subjects DRF Flashup	PT Dive subjects DRF Flashup	PT & HPNS tests Dive subjects
	HPNS tests	HPNS tests Chamber	HPNS test Equipment, subject scientific prep	HPNS tests Equipment, subject scientific prep	HPNS tests
1015/ 1030	COFFEE BREAK	COFFEE BREAK	COFFEE BREAK	COFFEE BREAK	COFFEE BREAK
1115	Protocol & test briefings. All subjects	Divematics system familiarization	GSOL test C- surface main system test Diver monitor test	DIVEMATICS	FLOW TRIAL
	SOHM Resign consent forms OK	Divematics system familiarization	GSOL Test D Emerg Test O/C	Heliox 18B test -FCO suit O/C -DRF CA OP/OP Board Patient Monitor	FLOW TRIAL
1200/ 1300	LUNCH	LUNCH	LUNCH	LUNCH	LUNCH
1345	Diver and patient monitor. Famil/ scientific co-ord meeting	Divematics famil continued	Divematics main system test surface		Chamber cleaning
	Diver and patient monitor. Famil/ scientific co-ord meeting	DRF watch/scientific briefing	Divematics emergency trial O/C	Living chamber cleanup	
1430/ 1445	COFFEE BREAK	COFFEE BREAK	COFFEE BREAK	COFFEE BREAK	COFFEE BREAK
1530	Diver and patient monitor. Famil/ scientific co-ord meeting	FCO suit famil	Operator training Dives as required 2 Flow Trial Dives	Operator training Dives as required T/C	
	Diver and patient monitor. Famil/ scientific co-ord meeting				

FIGURE 5

LOGISTICS

2.11 In preparation for SAT-DIVES 1/85 and 2/85, the following consummables were purchased:

a. helium 360,000 cu.ft.;
b. oxygen 100 cylinders;
d. soda lime 125 40 lb. tins; and
d. O_2 fuel cells 18.

The following miscellaneous equipment and supplies were also purchased for SAT-DIVES 1/85 and 2/85:

a. ECL canister transport tubes;
b. microwave oven;
c. additional durette clothing;
d. air hoist for canister filling room;
e. subject entertainment materials;
f. VCR rental movies; and
g. toaster.

2.12 For SAT-DIVE 1/85 the DCIEM Cafeteria staff prepared all the subject and watch meals. This worked extremely well but placed an unacceptable burden on the small staff. For SAT-DIVE 2/85 an arrangement was made with the CFB Toronto combined mess. There were extreme problems in transport, communication and quality so after the first week the in-house staff again took on the task. For any future dives a catering company should be used.

SUMMARY

2.13 In summary, the operational pre-dive arrangements and training requirements were extensive, difficult to coordinate but proved to be an invaluable learning experience for all the participants. This experience could have been enhanced if greater recognition had been given to the subjects previous familiarity with the test equipment. This would have freed more time to progress watch/operations, scientific medical team cohesiveness.

SECTION 3

ENGINEERING PRE-DIVE ARRANGEMENTS

GENERAL

3.1 The pre-dive engineering requirements were quite extensive and they can be divided into 3 areas; chamber interfaces, chamber equipment work, and logistics requirements. The electronics work required is also covered in this section.

CHAMBER INTERFACES

3.2 The following chamber interfaces were required:

a. **Scientific/Medical Monitoring**

The various types of monitoring equipment that required interfacing are described in detail in Section 4. All major electrical interfaces however, went through the existing chamber scientific panels. One special penetrator/manifold was developed to interface up to 6 small gas sample lines from the diver's helmet to the mass spectrometer;

b. **Gas Services Equipment**

Three connections were required to interface the diver's helmet in the DRF with the pseudobell equipment in the Mobile Test Facility (MTF). These connections were for gas supply, gas return, and pressure tracking. This was accomplished by using 3 hoses running from the MTF to hull isolation valves on 3 standard DRF dive chamber penetrators (Figure 6). The penetrator details and lengths of required hoses had been provided to the GSOL personnel during a pre-setup visit and they brought hoses with the appropriate fittings;

c. **Divematic's Sumbersible Divers Heating Unit (SDHU)**

The SDHU consisted of a surface power supply and control unit which required an electrical connection to a heater/pump unit mounted in the DRF wetpot (Figure 7). The connections were accomplished using custom penetrators which maintained electrical isolation and ensured the conductor jacketing was electrically grounded to the chamber. A supply and return hose connected the heater/pump unit to a manifold supplying a co-axial hot water hose attached to the diver's umbilical;

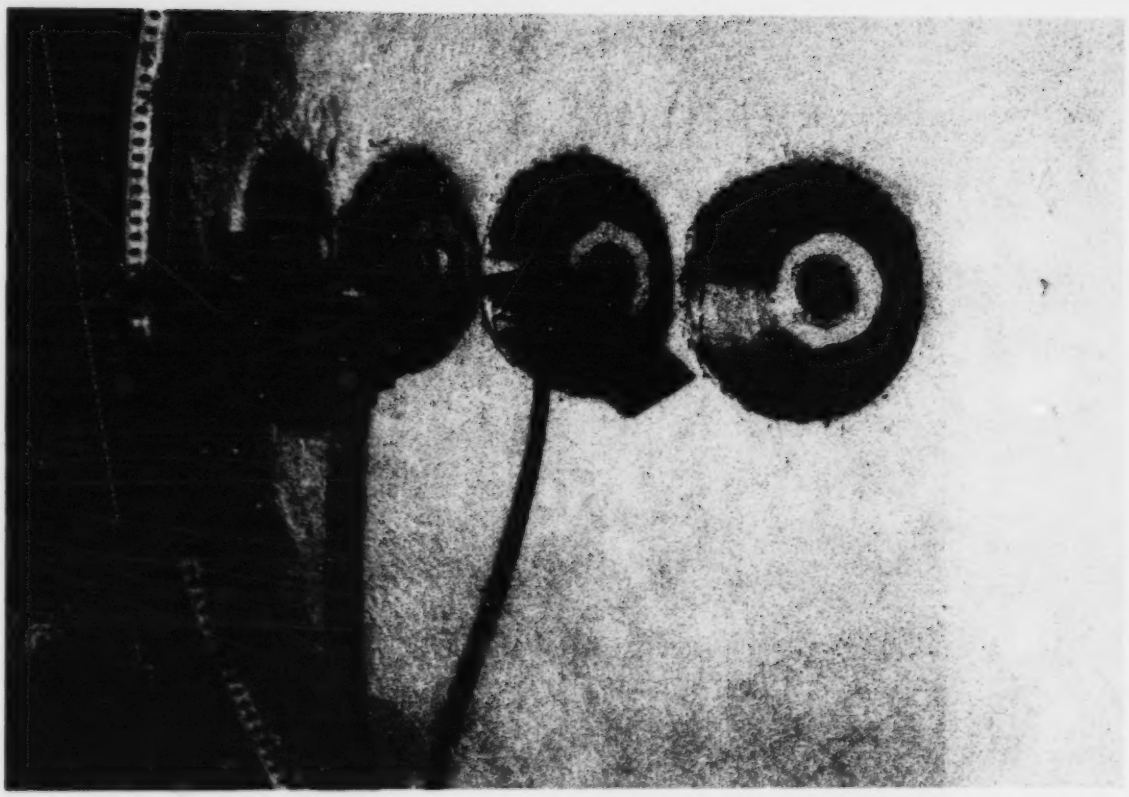


FIGURE 6

DRF EXTERNAL PENETRATORS USED FOR MTF HOOKUP

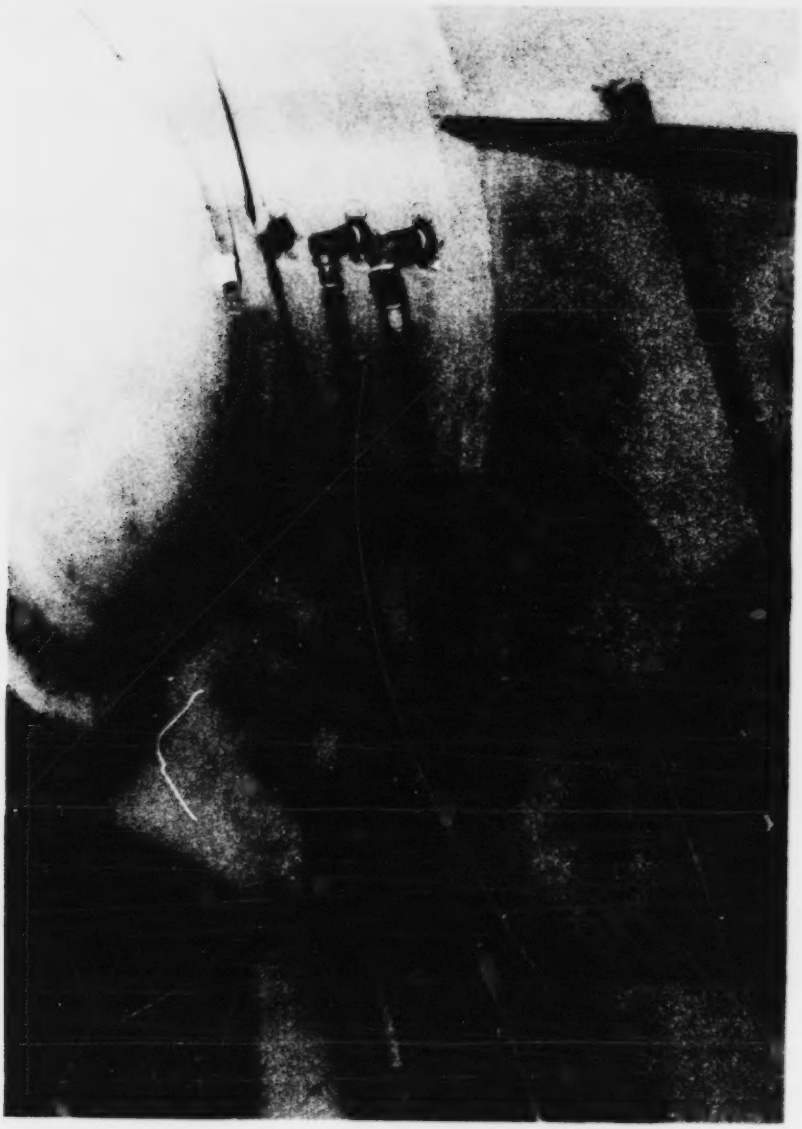


FIGURE 6

(continued)

DRF INTERNAL PENETRATORS USED FOR MTF HOOKUP

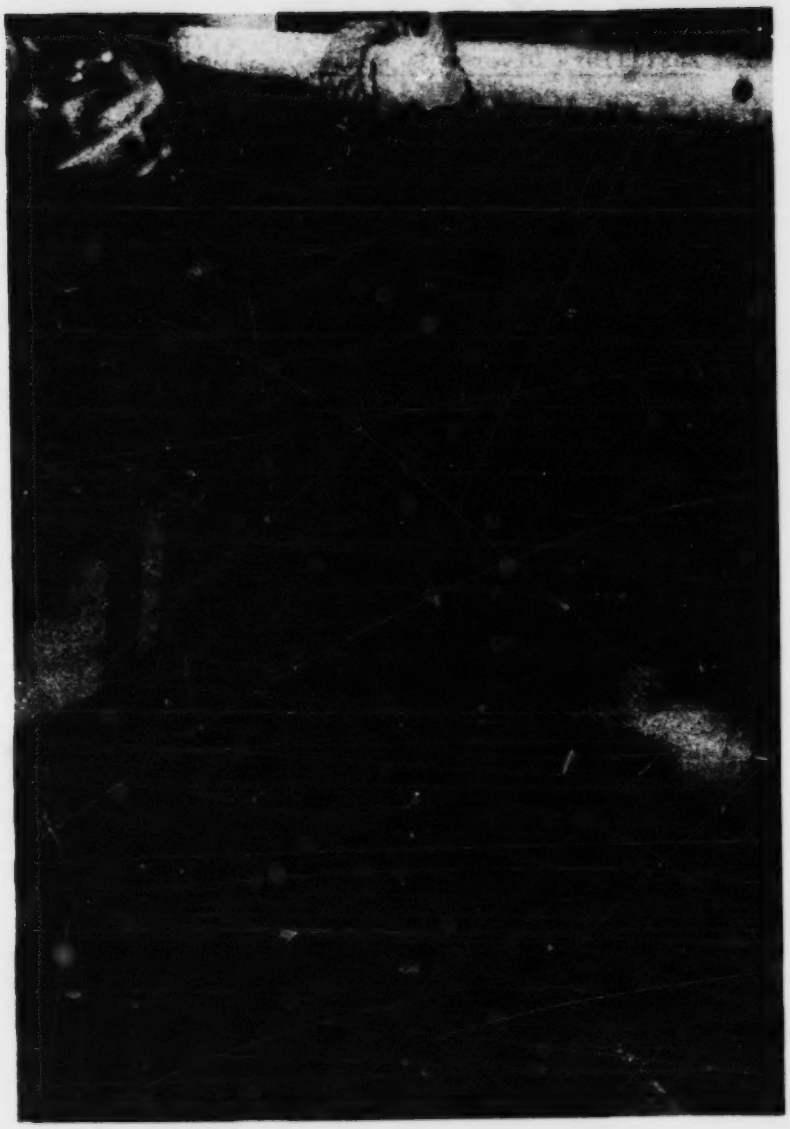


FIGURE 7

SUBMERSIBLE DIVERS HEATING UNIT MOUNTED IN THE DRF WETPOT

again, the penetrator details had been provided to the manufacturer during a pre-setup visit and he arrived with the custom made pieces to fit the DRF. In all cases, this approach worked well and is considered essential for any future endeavours of this nature; and

d. **Auxilliary Diver's Supplies**

Supplies not provided by the test equipment were obtained from the various built-in systems. Hot water for the 2 open-circuit suits and the gas heating shrouds were provided by the existing Environmental Conditioning Unit (ECU). The gas for the diver's emergency supply, the standby diver's rig, and the Divematics Closed-circuit suit inflation was routed through the Supervisors Medical Officers Console (SMOC) panel to the existing manifolds in the Dive Chamber (DC).

CHAMBER EQUIPMENT WORK

3.3 a. **Maintenance**

A major effort was required prior to SAT-DIVE 2/85 on chamber and compressor maintenance. The sanitary system was modified to alleviate the trap blockages identified in SAT-Dive 1/85. On completion of the chamber maintenance, full system integrity was finalized with a successful certification pressurization to 360 msw;

b. **BIBS**

Extensive unmanned testing of the BIBS supply system and the BIBS masks after SAT-DIVE 1/85 indicated that the fitted BIBS mask capabilities would be insufficient at the maximum depth of 360 msw for anything other than a resting diver. It was thus decided to use a proven open-circuit diver's mask as the emergency breathing apparatus to provide for the possibility of higher workloads. The overbottom delivery pressure was increased to 140 psi to accommodate the new emergency mask. The original masks with overboard dump were also taken in case of a requirement for decompression treatments. The old mask operated satisfactorily at this higher pressure. Further details on this testing will be reported by Mr. D. Eaton under separate cover;

c. **Oxygen Makeup System**

This sytem was modified to ensure oxygen makeup rates appropriate to the depth of 360 msw and to eliminate pO_2 swings due to over compensation. Orifices proportional to chamber volumes were installed to meter this oxygen flow. With the

orifices installed, the automatic O_2 makeup system now increases the oxygen partial pressure by approximately 1mmHg per minute whereas the manual makeup system adds O_2 in the range of 4mmHg per minute; and

d. **Diver's Hot Water System**

It was anticipated that at the greater depths the diver would require a considerable increase in hot water flow especially to the hot water shroud. To satisfy this requirement, the hot water piping was modified and the steam control valve was replaced to prepare for the anticipated increased demand for hot water supply. There were some further problems also as the steam supply pressure fluctuated and the installed system flow meter was not sufficiently robust nor easily repaired.

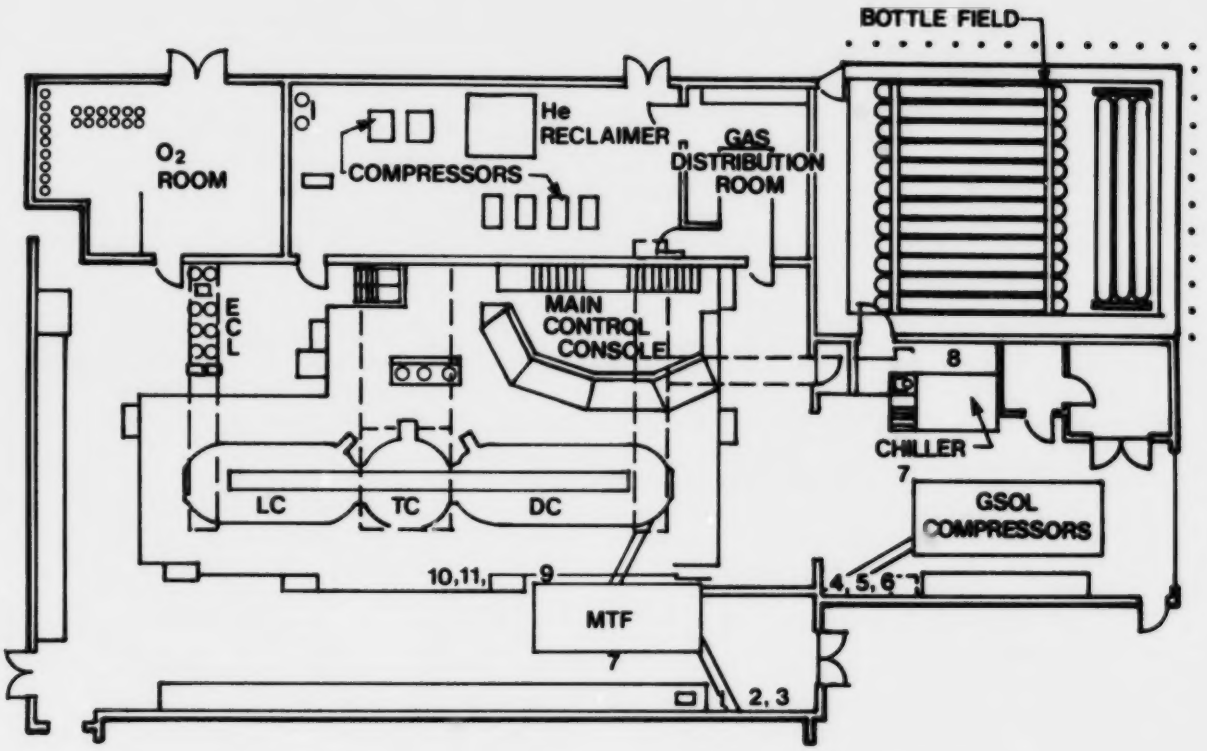
LOGISTICS

3.4 The majority of the equipment arrived by truck in 2 20' sea containers. The containers were offloaded and positioned by an equipment moving contractor. This contractor was organized through the base traffic section. The container which served as the MTF was located adjacent to the DC in the scientific area. This allowed the systems in the MTF to be close coupled to the DRF and permitted good communication with the scientific personnel. The second container which held the 2 large compressors and other gas handling equipment was situated in the garage. This location isolated the container's noise and heat-producing equipment from the chamber area.

The services required for the test equipment were water, gases, and electrical power. The various services and their locations are illustrated in the DRF Floor Plan (Figure 8). Three water supplies were required. The gas handling equipment used 30 gpm for cooling and the vessels in the MTF was required to be full of water for the tests. A floor drain beside each container was used for water discharges. The gases involved were oxygen supplied from transport cylinders beside the MTF, and helium/oxygen mixes supplied through the Diving Training Facility (DTF) piping from the mixed gas distribution panel. Excess and exhausted gases were vented into the reclaimer storage bags through the wetpot water level control system. The electrical requirements were typical of the United Kingdom and were not the North American standard. The necessary supplies were 440 Volt, 3-phase, 60Hz, and 220 Volt, 50 Hz. To meet these requirements, a 440 Volt transformer (75 KVA) and a 220 Volt motor generator (10 KVA - 550 Volt building supply driven) were rented. It was thought that the demands of the various instrumentation and the SDHU would require a second transformer, however, the building 208 V, 60Hz supply proved adequate and eventually the motor generator was returned.

Figure 8

DRF Floor Plan



1. 208V, 1Ø, 60Hz, 20 Amp
2. Water for filling vessels.
3. Mixed gas.
4. 418V, 3Ø, 60Hz, 35 KVA
5. 440V, 3Ø, 60Hz, 75 KVA
6. 220V, 1Ø, 50Hz, 10 KVA
7. Floor Drains.
8. Cooling water.
9. Oxygen transport cylinder.
10. Communications.
11. Video.

The numerous interconnections between the DRF, the 2 containers and the various services were made overhead to allow unobstructed movement on the floor. The DRF Floorplan illustrates the routes for the interconnections. The water and gas hoses were supplied by Gas Services and connected by our staff. The electrical wiring was primarily performed by a civilian outside contractor with secondary hookup by Gas Services and DCIEM staff. The wire and switch/fuse panels were provided by the contractor. The secondary wires, grounding and ground fault protectors were provided by DCIEM.

ELECTRONICS PRE-DIVE REQUIREMENTS

3.5 The work requirements for the Diving Electronics Laborary (DEL) divided into 2 main areas:

a. facility instrumentation maintenance; and
b. facility communications.

FACILITY INSTRUMENTATION

3.6 a. **Pre-SAT-DIVE 1/85**

In preparation for SAT-DIVE 1/85, repairs were completed on the Hygrometers for the Transfer Chamber (TC) and the Living Chamber (LC).

DEL was also involved in the installation of video cameras at the DRF main door and in the bag room upstairs. This system contained a video monitor, video switch, cable, and connectors with the monitor situated on the Mixmaker rack. Two additional monitors were installed on the scientific side of the DRF floor and the TC chamber monitor was repaired.

A remote controlled door security system was installed on the DRF area main door with the control box installed on the main control floor above the mixmaker rack. At this point, all facility monitoring equipment were calibrated and serviceable.

b. **PRE-SAT-DIVE 2/85**

After the first dive, the O_2 controllers were rechecked for calibration. DEL also repaired and corrected an error on the DC CO_2 analyzer recorder output and replaced the main console clock which was working intermittently.

Two more video monitors were installed on the scientific side of the chamber to give a total of four, and a video camera was also relocated from the top to the end of the DC to give a better picture of the subjects.

The underwater camera was repaired and reinstalled in the DC. The gear mechanism was stripped and cleaned. The main connector was discovered to be filled with water. This was reinserted fully and tightened up.

Some slight problems with the VCR equipment were also addressed by cleaning the heads and tightening the legs on the loose plugs.

The Canty lights were all checked by DEL, resulting in 1 fuse and 6 lamps being replaced.

On completion of this work, all the facility instruments were then rechecked and calibrated just prior to the dive start.

FACILITY COMMUNICATIONS

3.7 Prior to the first dive it became evident that 3 problems existed with the communications setup. These were:

a. it was becoming old and its reliability was suspect with the quality and capability of the helium speech unscramblers unknown;

b. the system had been built and maintained by TSD since installation, thus, CEDD experience was limited; and

c. all the chamber communications went through the one central control console. If it failed, total communication would be lost.

In preparation therefore, the following approach was taken:

a. TSD undertook the training of the DEL personnel and conducted an overhaul of the system. In addition, a stockpile of spare parts was set up in the DEL;

b. one Helle 3340 unscrambler and one Marconi DSD34-2 unscramblers were prepared for the dive. Additionally, two Marconi DSO34-2 unscramblers were obtained from ARE(PL) and Helle 3312 and 3316 unscramblers were obtained from CanDive.

Two Helle 3342 unscramblers normally used at the DRF were also made available. The intention was to have available different types of unscramblers for the dive in case the installed unscramblers failed or proved unsuitable;

c. two Marconi unscramblers were installed at the main communications panel; and

d. an emergency backup communications system was developed and installed to provide two outside stations and one station/chamber inside. The system involved:

(1) two Helle 3342 unscramblers;

(2) a total of three, one-headset jack boxes containing preamplifiers and located in each chamber;

(3) one dual-headset (LC,TC,DC) station located near the supervisor's position at the main console;

(4) one battery power pack located at the scientific station; this power pack required switching to "ON" position when the emergency system was to be used; and

(5) one isolation circuit located with the power pack to protect the front end of the unscrambler from voltage feedback.

e. all helmets and masks to be used were fitted with DRF style communications including the new emergency masks that were to be used as BIBS masks; and

f. three external speakers were installed for monitoring purposes at the request of the Scientific staff. This was accomplished by using a 10 to 1 attenuator with input to a Challenger Bogan amplifier and installing speakers in the scientific area, the MTF, and the lounge areas. The whole system was sourced from headset position #13 on the scientific side.

3.8 During SAT-Dive 1/85, several problems developed and some corrective actions were carried out as shown:

a. an intermittent ground fault caused the main communications system to trip out on five occasions during the same time period three nights in a row. To prevent further failures, the communications system was powered from another panel for the remainder of the dive;

b. over the course of the dive communications with in-water divers deteriorated, eventually culminating in a total loss of voice communications from that source; the problem was

traced back to the preamplifier box located in the dive chamber and a variable attenuator was installed in the box, however with little success;

c. divers in the facility had no means to attract attention of the main control panel operators when the operators were not wearing their headsets;

d. the two Marconi unscramblers were unacceptable for the main communication system and they were replaced with the two Helle 3342 unscramblers originally with the emergency communications system, producing significant enhancement in the quality of the unscrambled communications;

e. in the emergency communication system, the removed unscramblers were substituted by one Helle 3340 unit without adverse effects on the operation of the system, however, the battery pack supplying the system proved to be inadequate to maintain a continuous operation.

3.9 After the SAT-Dive 1/85, but before SAT-Dive 2/85, the following corrective measures were taken:

a. the power connection to the communication system was reinstated to the original position upon checking and retightening of all connections;

b. the loss of communications with in-water divers during SAT-Dive 1/85 was traced to the chamber station grounding to the chamber hull, a lucite plate was installed between the box and the chamber to elliminate the problem;

c. a push-button was installed in the living chamber to provide the divers with a call buzzer to the main control console in case of an emergency call requirement;

d. communications components in all helmets and umbilicals were overhauled and all new microphones and earphones were installed;

e. the battery pack in the emergency communications system was replaced by a power supply to provide the capability of a continuous operations;

f. two 100 msw helium bounce dives were carried out on completion of the modifications to test the efficiency of the modified system and the results were positive;

g. the new emergency masks that were to be used as BIBS masks for SAT-DIVE 2/85 were fitted with the BIBLS mask type mikes

d. communications components in all helmets and umbilicals were overhauled and all new microphones and earphones were installed;

e. the battery pack in the emergency communications system was replaced by a power supply to provide the capability of a continuous operation;

f. two 100 msw helium bounce dives were carried out on completion of the modifications to test the efficiency of the modified system and the results were positive;

g. the new emergency masks that were to be used as BIBS masks for SAT-Dive 2/85 were fitted with the BIBS mask type mikes to obtain impedence matching; and

h. external speakers were installed in the scientific area, the MTF, and the lounge areas for monitoring purposes; the system was sourced from the headset position #13 on the scientific side and a 10 to 1 attenuator was used at the input to a challenger Bogen amplifier feeding the speakers.

3.10 During the SAT-Dive 2/85 a few problems also developed but they were corrected as follows:

a. the intermittent ground fault on the main communications panel was still present and caused communications panel breaker to trip out a few days into the dive. The communications panel was once again powered from another panel resulting in no further power delivery problem;

b. communications with in-water divers started to deteriorate again; helmet microphones, communications whips, umbilicals and diver communications box batteries were all replaced. Then communication improved throughout the dive with adjustments of the unscramblers and occassional changing of batteries, however, a root cause of the problem was never isolated.

SECTION 4

SCIENTIFIC PRE-DIVE DETAILS

GENERAL

4.1 The scientific equipment and data acquisition setup for the dive was designed to satisfy the requirements of the dive program. A short description of the scientific instrumentation and equipment placed in the chambers and on the scientific floor, outside the chambers has been provided. The general scientific floor layout for the dive was as shown in Figure 9. A permanent scientific (electrical) interface system (Reference 1), connecting outside and inside user stations (Figure 10) at each of the 3 chambers of the facility, provided the link between the instrumentation placed within the chambers and the external monitoring equipment.

CHAMBER EQUIPMENT

4.2 a. **DC**

The wetpot of the DC was equipped with a remotely (surface) controlled upright Collins Pedalmate ergometer (Figure 11), modified for underwater use and positioned on one side of the wetpot. A swim bar was situated on the other side of the wetpot. A nut puzzle was placed close to the entry barriers and a valve assembly was setup behind the ergometer at the back of the wetpot. The nut puzzle and the valve assembly were provided by Norsk Hydro to maintain continuity of test conditions in the international testing program on diving life-support systems for the Oseberg Transportation Project (OTP).

The dry side of the DC contained all umbilical terminations. Apart from the divers life-support systems, there was a hot water distribution system used to supply divers' suits and heat the inhaled gas. The SMOC panel operator provided manual control of the hot water flow to the divers. A splitter block with a controlling orifice at the diver was used to set the ratio of the flow to the shroud on the helmet and the suit (Figure 12). The pressure differential between the oral-nasal mask and the exterior of the diver's helmet was measured using long tubes bundled with the main umbilical and connected to a Validyne DP-15 pressure sensor located in the dry side of the DC. A U-tube water manometer was used with the chamber to calibrate the pressure sensor (Figure 13).

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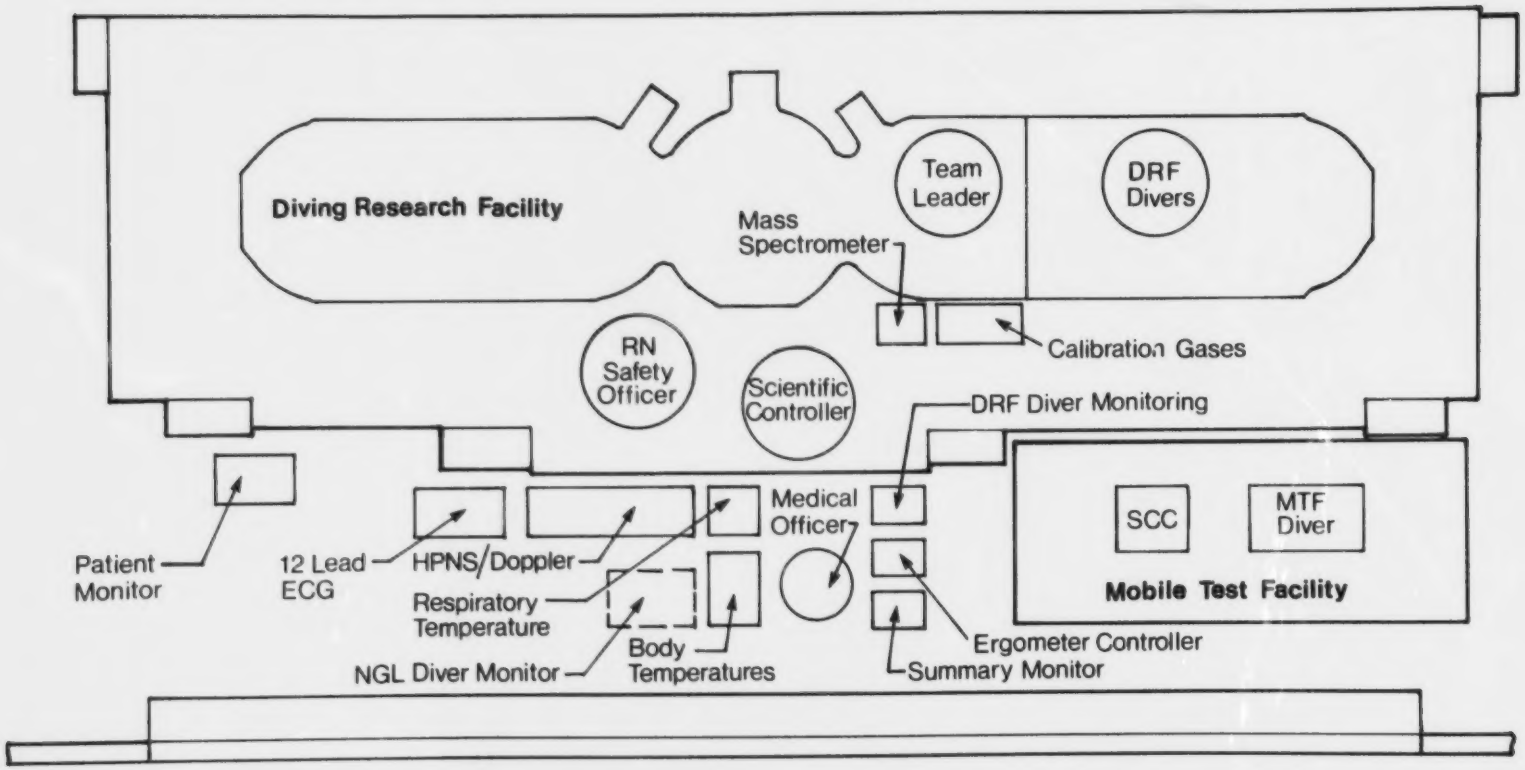
Reference 1: L.V. Allin et al. Scientific Interface System for the DCIEM Diving Research Facility. DCIEM Technical Communication No.81-C-15.



Scientific Data Aquisition Floor Plan

Figure 9

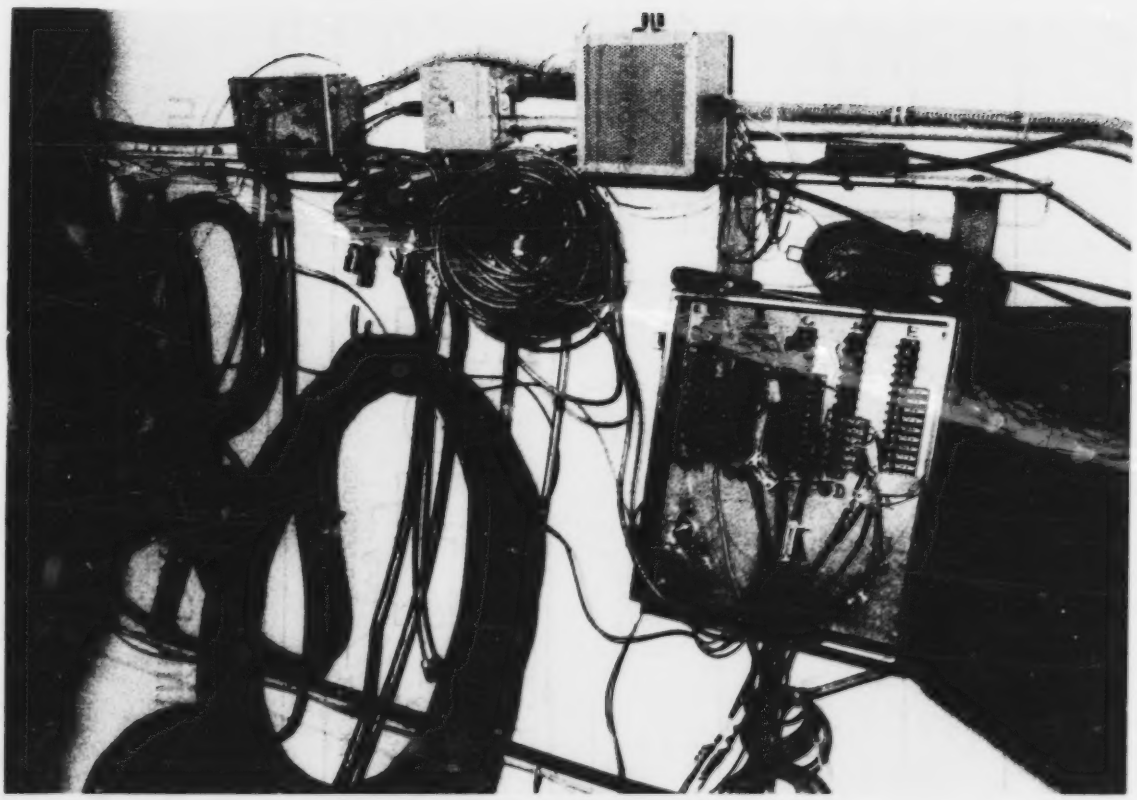


FIGURE 10

DRF WETPOT SCIENTIFIC INTERFACE PANEL

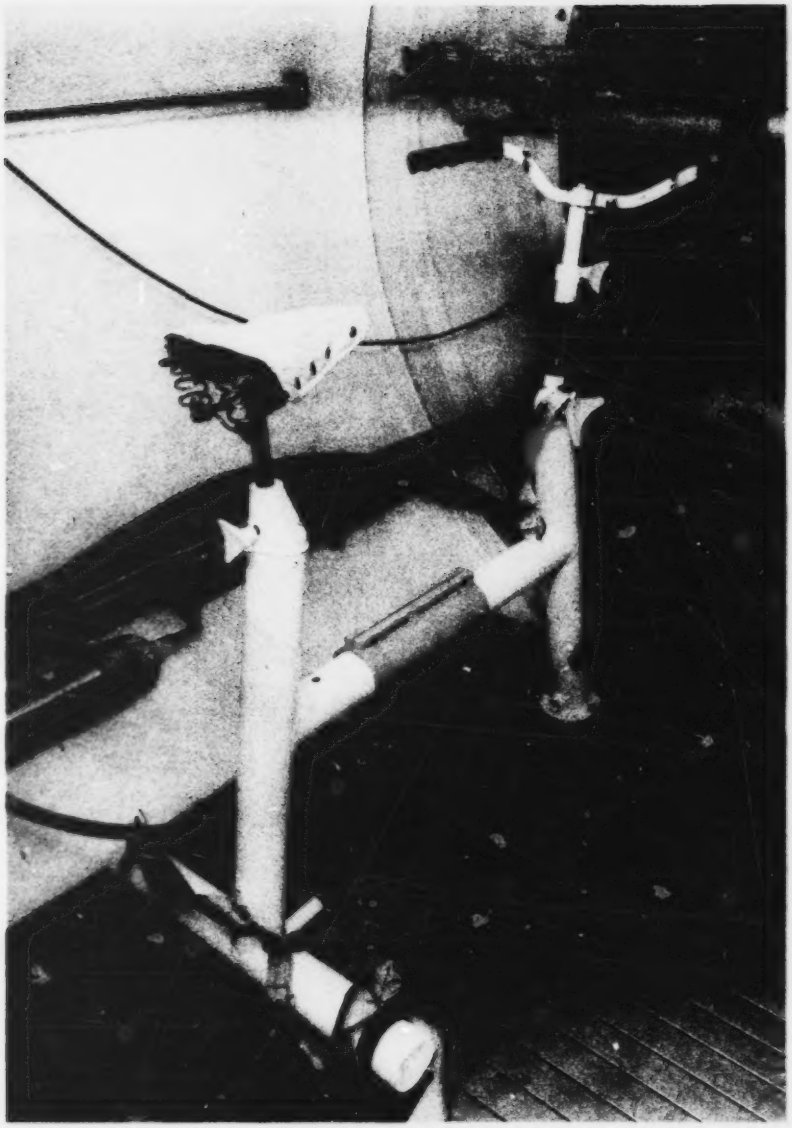


FIGURE 11

COLLINS PEDALMATE ERGOMETER

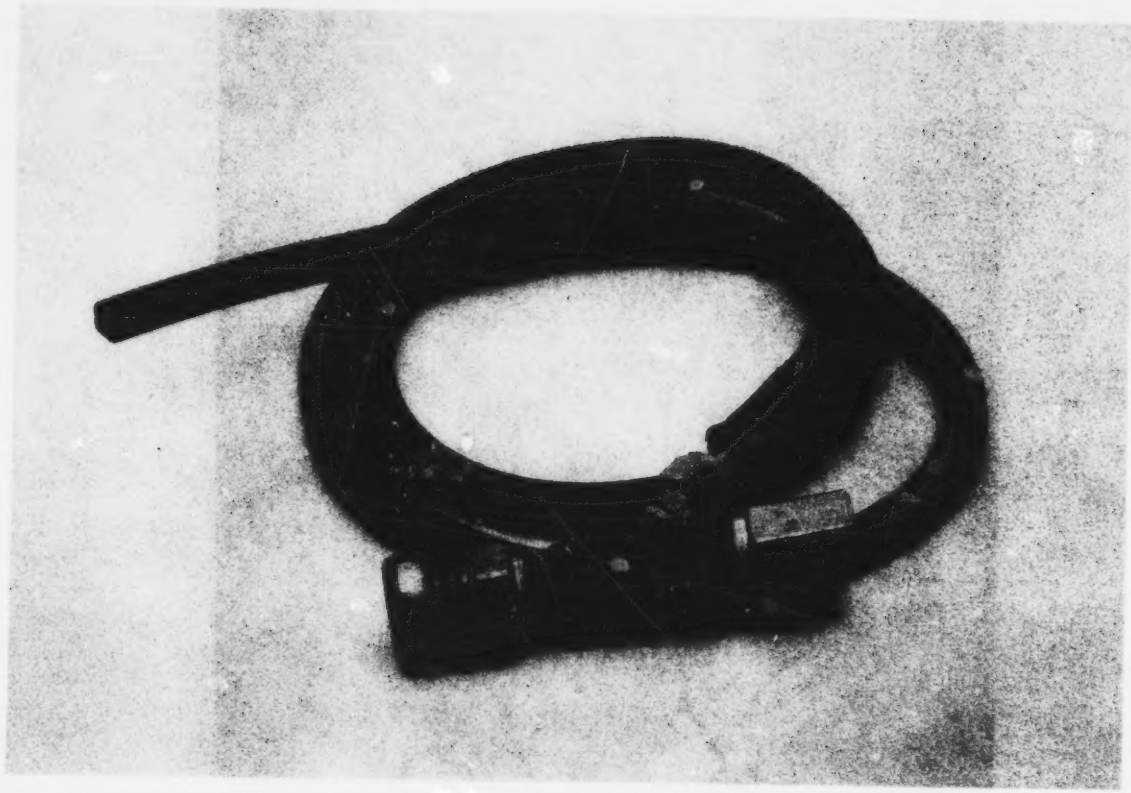


FIGURE 12

HOT WATER UMBILICAL SPLITTER BLOCK

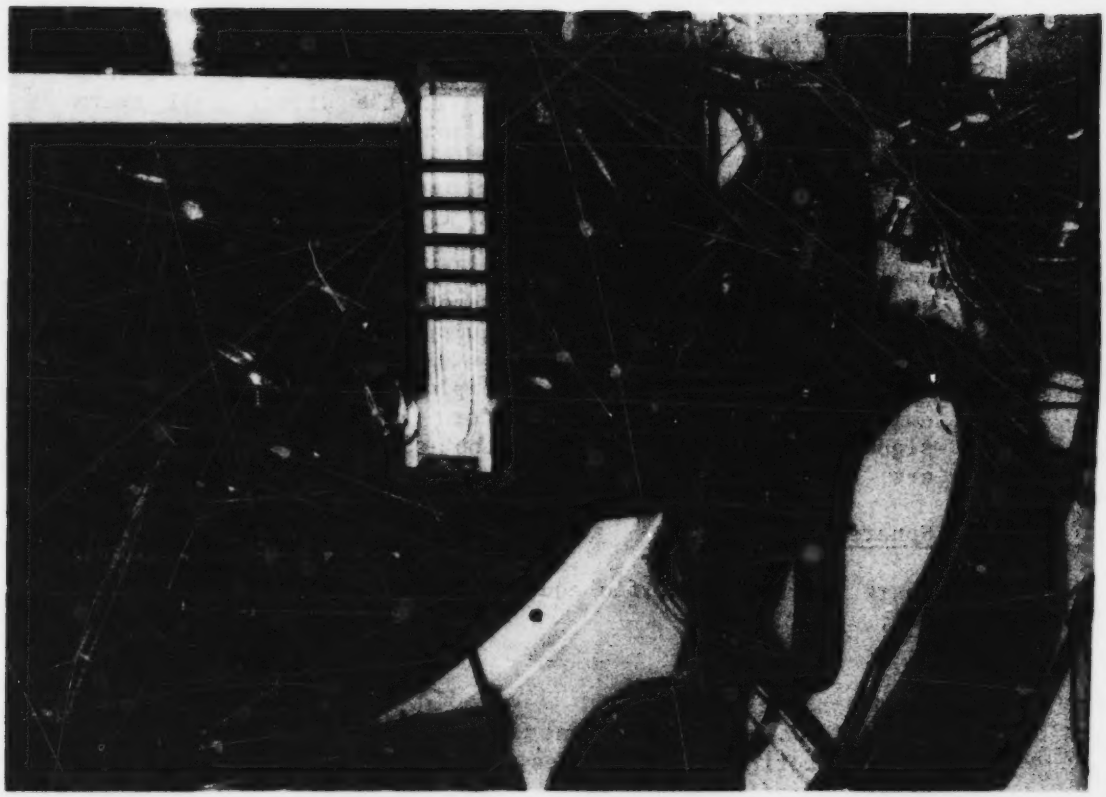


FIGURE 13

GSOL HELMET AND Δ p CALIBRATION MANOMETER IN WETPOT

The oral-nasal mask within the helmet (Figures 14 and 15) was also equipped with gas sampling lines connected through small diameter tubing penetrating the chamber wall to an externally located mass spectrometer. A 7-thermistor harness with a common ground was provided for the working subject to monitor his body temperature (Figure 16). A miniature thermistor was mounted in the large bore of the gas delivery tube of the helmet (Figure 14) to monitor the inhale/exhale gas temperature. A splitter block thermistor was setup to monitor temperature of the hot water supply at the diver. All thermistors were connected to cables bundled with the main umbilical and connected to external monitors via the interface stations. Diver's electrocardiograph (ECG) was monitored using 3-wire harness hard wired to an external monitor via the interface panels. An NGL diver medical monitoring system was also placed in the chamber. It involved a thoracic belt assembly for physiological parameters and suit temperature monitoring. The helmet was equipped with a bent tube side block assembly incorporating a thermistor to measure the supply gas temperature. A multiplexer unit encoded the data collected from the sensors for transmission through two signal-carrying conductors to the externally located recorders;

b. **Sphere**

There was no scientific equipment in this part of the facility;

c. **LC**

The LC contained equipment facilitating 12-lead and 3-lead ECG monitoring, HPNS studies, bubble Doppler studies, and NGL patient monitor application. The twelve lead ECG monitoring was facilitated by a pre-amplifier placed close to the subject within the chamber and interfaced to an external monitor. A Siemens 3 lead ECG pre-amplifier transmitter was placed in the chamber to test its performance when pressurized. An internal antenna picked up the signal for hard wire transmission to external monitors via the interface system. The HPNS system also involved a package of instrumentation interfaced to external monitors. An ultrasonic probe was used for the Doppler monitoring. An NGL patient medical monitoring multiplexer and associated sensors and probes were prepared for use in the chamber to permit the monitoring of a patient's physiological characteristics.

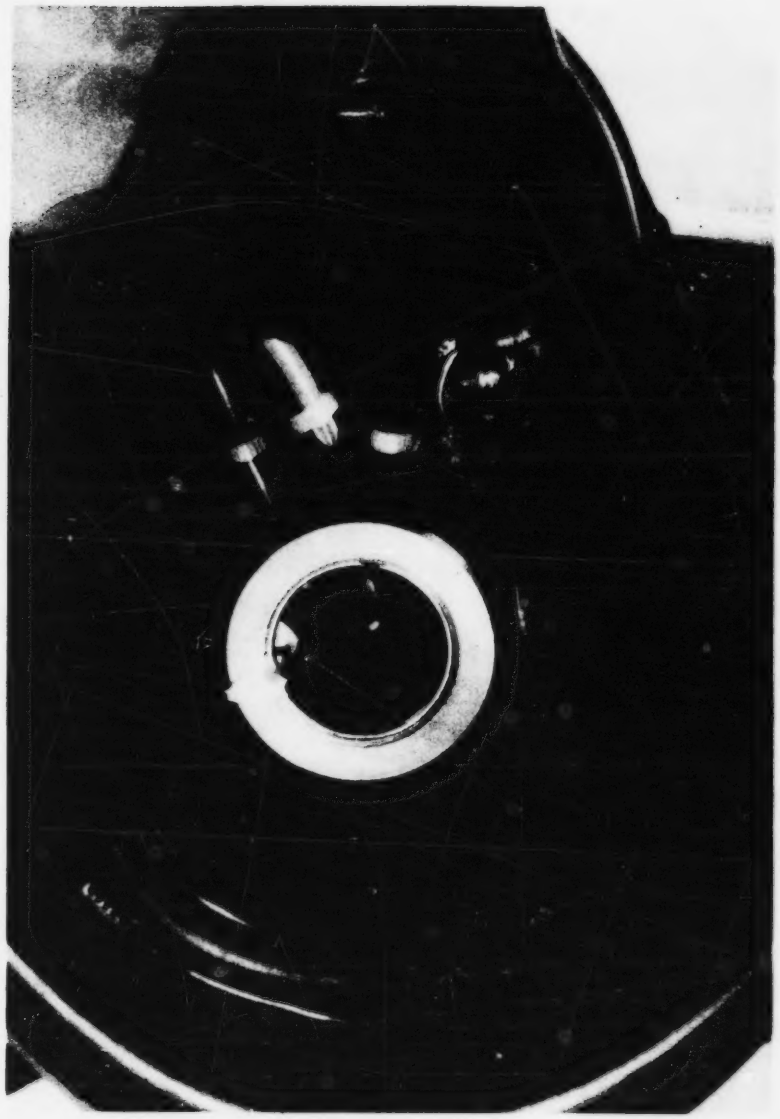


FIGURE 14

ORAL-NASAL MONITORING ARRANGEMENT

GAS, Δ p AND TEMPERATURE

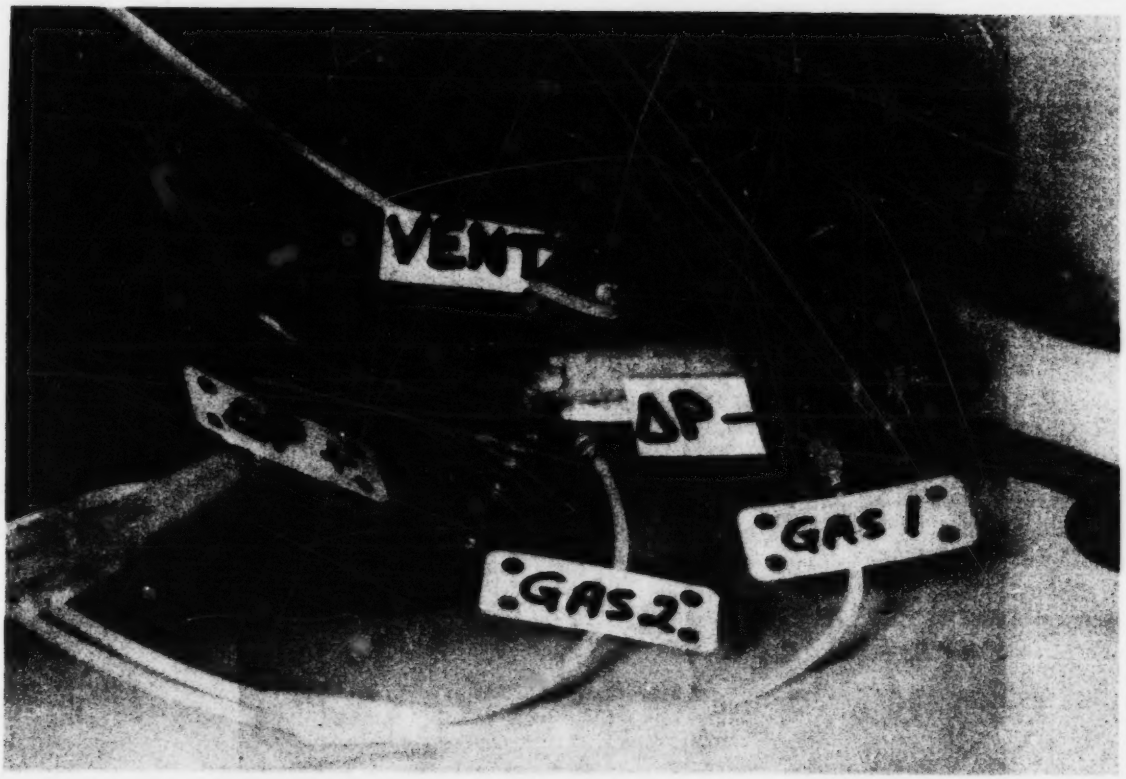


FIGURE 15

HELMET GAS AND PRESSURE MONITOR ARRANGEMENT

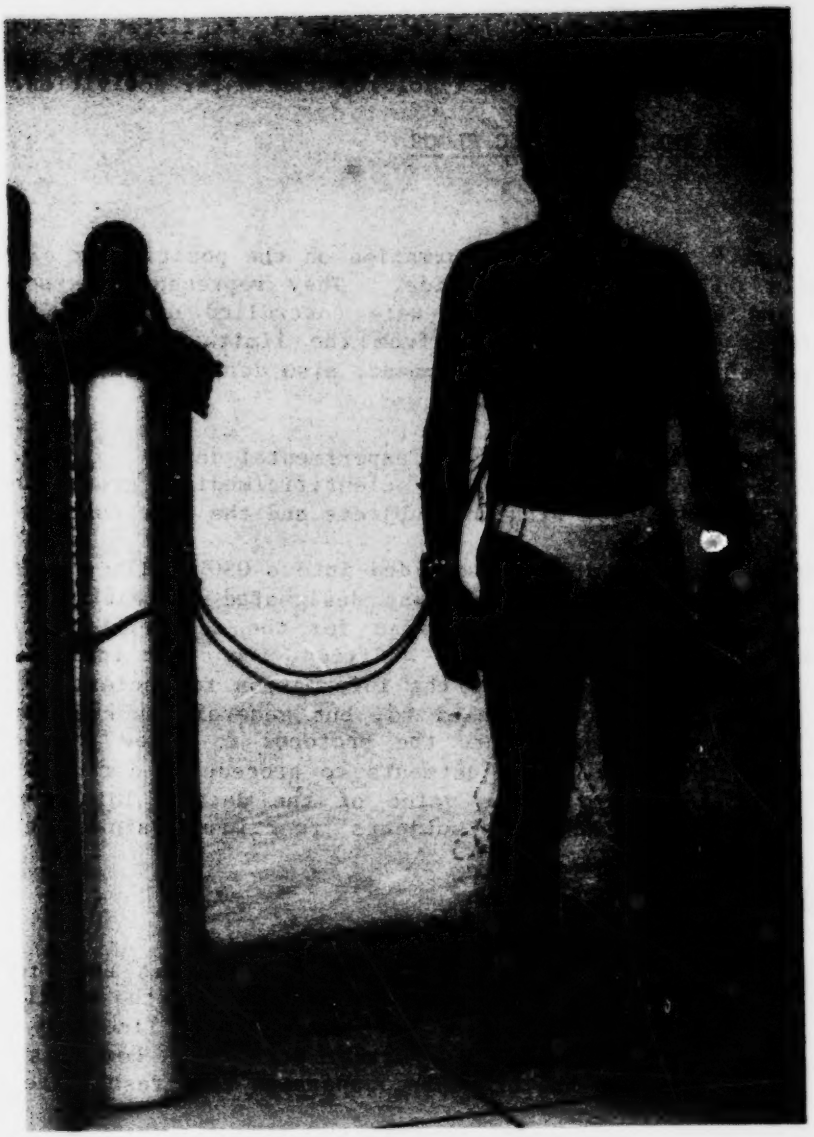


FIGURE 16

SUBJECT THERMAL MONITORING PACKAGE

A dry Monarch ergometer prepared for hyperbaric environment service was placed in the chamber to facilitate assessment of subject's ability to work at the high pressure conditions prior to experiments involving underwater activities.

ORGANIZATION OF THE SCIENTIFIC FLOOR

PERSONNEL

4.3 Figure 9 provides the information on the positioning of the main individuals on the scientific side. They represent the scientific, medical, and safety aspects that were controlled during each experiment. Their placement resulted from the limitations imposed by the arrangement of the scientific equipment, also depicted in Figure 9. The arrangement had to facilitate:

a. real-time readout of the experimental data;
b. communication within the scientific/medical group; and
c. communication with the subjects and the main control panel.

4.4 The scientific area was divided into a GSOL cell, a thermal cell and medical cell. An individual was designated "scientific" for each experiment and he acted as spokesman for the scientific side on the operations communications net. In addition, one other individual acted as floor co-ordinator filtering the information to "scientific". This setup took some time getting used to, but generally worked very well. Some flexibility was built into the protocol to allow the scientific support side to make minor adjustments to procedures during the course of any trial to maximize the value of the data. This worked well provided personnel balanced the subjects' reactions against the value of the extra data.

EQUIPMENT

4.5 A Chemetron, Medspect II mass spectrometer was used to measure the carbon dioxide levels in the respired gases of the working diver. The spectrometer was calibrated and checked for linearity at each experimental depth in the dive. Further details on how this was conducted are contained in the breathing apparatus test results report.

4.6 The heart rate (HR) of the diver-subject was monitored using a Riegel Cardiac Monitor 302. A Validyne demodulator/monitor unit measured the pressure signal (p) from the DP-15 pressure sensor. The inhale/exhale thermistor output was monitored directly by a YEW type 3056 three-channel strip chart recorder. This signal was also monitored on a Gould Brush 260 six-channel recorder along with p, $ppCO_2$, and HR signals which were continuously recorded during each experimental period at a fixed chart speed. The 3 signals: p, $ppCO_2$, and HR were additionally recorded on a Gould 2600 three-channel recorder providing wide strip recordings. The chart speed on this recorder was altered to suit the momentary requirements.

4.7 Digital data acquisition was carried out using HP 9825 desk top computer to provide a minute-by-minute update of the status of the diver and his environment, primarily for the Medical Officer. Minimal and maximal values of $ppCO_2$, HR, p, inhale/exhale temperature, water temperature, and air temperature on the dry side of the DC were displayed each minute on a monitor allowing a quick assessment of trends and their relationship to the abort criteria. This information was also provided on-site in a printed version.

4.8 Skin and core temperatures were measured by YSI thermistors and continually monitored by a Hewlett Packard data acquisition system (HP 85 computer, 3497A scanner/voltmeter). Minute averages were recorded on data tape and plotted on a 9872A plotter to facilitate the assessment of divers' thermal comfort and safety.

PRE-DIVE LOGISTICS

4.9 The experimental instrumentation and related materials required for each test during the dive and the authority responsible for their provision were identified through co-operative efforts with the British and Norwegian participants. Orderly preparations of the scientific aspects of the dive were therefore, facilitated by this co-operation.

4.10 Assistance was provided to the RN in procurement of specialty gas mixes which corresponded to the depths simulated within the hyperbaric chambers for purposes of calibration.

4.11 The majority of the scientific equipment used in the experiments was available at DCIEM. Some equipment however was provided by the ARE(PL) and NUTEC. Assistance was provided to the Norwegian Team and the NGL personnel in obtaining transformers, other materials, and services to check their equipment, repair, and setup.

4.12 Pre-dive work involved preparation of the scientific, recording, and data acquisition equipment. Checks were made to ensure that the electrical connections between the in-chamber and the external equipment were working correctly. Extensive tests were also carried out to assess the capability to carry out mass spectrometric measurements. Calibrations were done both prior to the dive and during the dive, as required.

SECTION 5

MEDICAL PRE-DIVE ARRANGEMENTS

NEUROLOGICAL TESTING

5.1 Prior to the dive, the following battery of tests were undertaken by each subject:

a. neurology examination (done by INM);

b. sixteen lead Electroencephalograph (EEG) (arranged by the Institute of Naval Medicine (INM);

c. caloric vestibular function testing/electronystagmography (ear, nose, throat (ENT) Dept., National Defence Medical Centre (NDMC), Ottawa);

d. baseline force platform measurements (DCIEM); and

e. **Neuropsychological Tests (arranged at DCIEM by NUTEC)**

Adaptive abilities, lateral dominance, co-ordination, vertical and horizontal groove steadiness, postural and resting tremor, unilateral and bilateral imperception, finger agnosia, tactile forms, grooved pegboard, Wechsler memory scale, forced choice memory, autonomic reactivity and clinical interview. (Also Fast Fourier Transform analysis of the EEG).

MEDICAL EXAMINATIONS

5.2 Prior to the dive, each subject was examined according to the following protocol:

a. general medical history and physical exam; (as per UEG commercial divers questionnaire and examination) to include height in cm (barefoot) and weight (nude) to nearest 0.1 kg;

b. chest and long bone x-rays; full size, AP and lateral chest films within the past year. Osteonecrosis series: AP of hips and shoulders, lateral of knees;

c. ECG: Standard twelve lead, resting (within the past year); also exercise (to exhaustion) ECG on bicycle erogometer or tread mill with MVO_2 measurement;

d. Audiogram: Air conduction thresholds for the frequencies 0.25, 0.5, 1, 2, 3, 4, 6, and 8 KHZ (as per ISO/DIS 8253);

e. Pulmonary Function Studies: To include FVC, FEV_1, PEF, MVV and diffusion capacity. (CO_2 and O_2 sensitivity tests performed by INM, and DCIEM (Central Medical Board) post-dive;

f. Skin Fold Measurement: Harpenden calipers, left biceps, triceps, subscapular and suprailiac measurement; and

g. urinalysis, including micro.

Following the surfacing of the dive, each subject was re-examined for the following:

a. general physical exam, as per medical examination section, para 4.2.a;

b. audiogram, as per pre-dive;

c. neurology examination by INM; and

d. force platform.

NOTE: 1. Subjects were to be available for a 1 year followup examination.

2. Pre and post-dive blood tests included CBC and ESR, electrolytes, calcium, phosphate, urea, creatinine, total protein, albumin, bilirubin, cholesterol triglycerides, carbamide, and sickle cell index.

FOOD

5.3 The medical officer reviewed and established the menu with the subjects and the galley staff prior to the dive pressurization. No special menu was used with subject weight loss taken as the determining factor in adjusting the menu.

ALCOHOL AND MEDICATIONS

5.4 No medications, either prescribed or over the counter were to be taken by dive subjects for 1 month pre-dive. It was recommended that minimal alcohol (i.e. a maximum of 2 beer or 2 1 1/4 oz drinks of liquor per day) be consumed for pre or post-dive. Post-dive the subjects were required to totally abstain until the completion of the medical and neurophysiological tests.

MEDICAL CHECKS

5.5 Daily medical checks were scheduled throughout the dive. Each dive subject was interviewed by the DMO. These interviews were confidential in nature between the dive subject and medical officer.

PRE-DIVE PHYSICAL FITNESS

5.6 The divers selected engaged in daily exercise similar to that anticipated during the dive for several weeks prior to compression (e.g. pedalling a stationary bicycle).

BEARDS

5.7 The divers going into saturation were clean shaven in order to prevent difficulties with mask fit should treatment be necessary.

SECTION 6

DIVE DETAILS

APPROACH

6.1 CAN/UK SAT-DIVE 2/85 was scheduled for a maximum period of twenty-eight days consisting of a descent of approximately 4 days to a storage depth of 360 msw with extended stops at 50 msw, 120 msw, 250 msw, and 320 msw enroute, 8 days on the bottom and sixteen days of decompression. The stops on compression were used to conduct RN Gasmizer trials. Once on the bottom, a complete range of evaluations on the trial equipment was conducted.

DIVE PROCEDURES

6.2 The following dive procedures applied to SAT-DIVE 2/85. Alterations to the Dive Profile other than for treatment of decompression sickness were to be done only on the recommendation of the RNTSO and with the approval of D/CEDD. Throughout this section, all gas mixtures are referred to giving the inert gas % first and oxygen % second (i.e. 80/20 Heliox).

COMPRESSION

6.3 The TC and DC were taken unmanned to 50 msw (80/20 HeO_2 to 15 msw then helium to 50 msw). The proper HeO_2 atmosphere (pO_2 = 0.5 Bar) was established in the TC and DC, then the dive subjects were pressurized to 15 msw in the LC with 80/20 HeO_2.

At 15 msw, the pO_2 = 0.5 Bar HeO_2 atmosphere was established in the LC and all systems were tested for satisfactory performance.

After all system functions were confirmed correct, the LC was pressurized to 50 msw with Helium at a rate not exceeding 1 metre/minute.

On completion of the 50 msw stop, the whole complex was taken to the next stop.

The rate of each subsequent move did not exceed the rates shown below for the appropriate depth range.

Depth	Travel Rate
0 - 120 msw	1msw/min
120 - 240 msw	.5msw/min
240 - 320 msw	.375msw/min
320 - 360 msw	.185msw/min

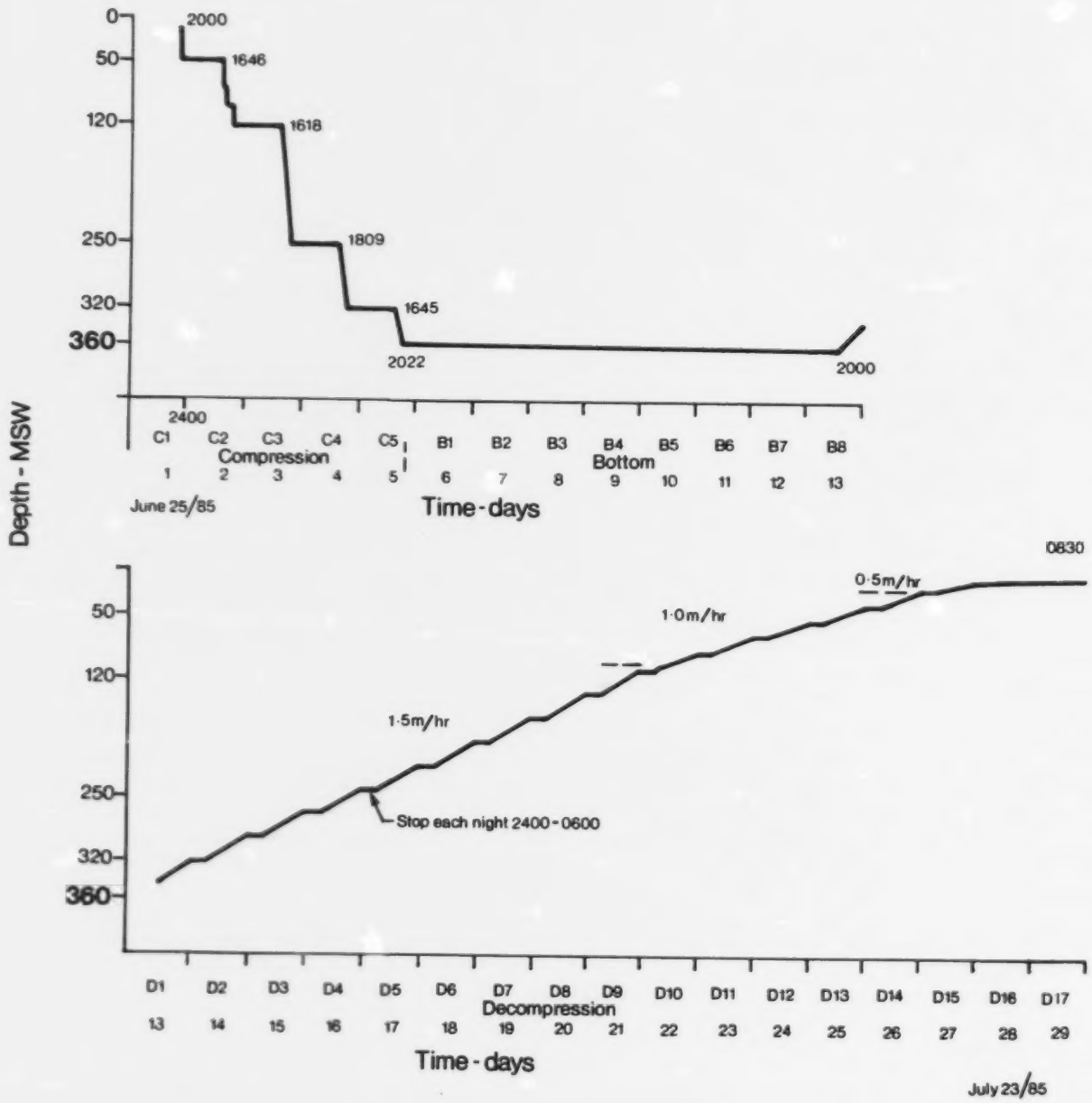
Table 2 details the compression rates and stop times, both planned and actual. Figure 17 shows the overall dive profile.

TABLE 2

COMPRESSION RATES AND STOP TIMES

Depth (msw)	Rate (msw/min)	Planned Travel Time (mins)	Actual Travel Time (mins)	Planned Stop Time (mins)	Actual Stop Time (mins)
0- 15	1.0	15	15	----	----
15	----	----	----	60	9
15- 50	1.0	35	35	----	----
50	----	----		(120+970)	(120+1067)
50- 80	1.0	30	30	----	----
80	----	----	----	60	61
80-100	1.0	20	19	----	----
100	----	----	----	120	120
100-120	1.0	20	20	----	----
120	----	----	----	(480+710)	(480+682)
120-240	0.5	240	240	----	----
240-250	0.375	27	26	----	----
250	----	----	----	(360+813)	(360+925)
250-320	0.375	187	187	----	----
320	----	----	----	(360+893)	(360+1559)
320-360	0.185	216	217	----	----

Figure 17


0
50
120
250
320
360
Depth - MSW
2000
1646
1618
1809
1645
2022
2000
2400
C1 C2 C3 C4 C5 B1 B2 B3 B4 B5 B6 B7 B8
Compression
Bottom
1 2 3 4 5 6 7 8 9 10 11 12 13
June 25/85
Time - days
0830
0·5m/hr
1·0m/hr
1·5m/hr
Stop each night 2400 - 0600
D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12 D13 D14 D15 D16 D17
Decompression
13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Time - days
July 23/85

Total compression time planned was approximately 4 days and actually took 4 days and 22 minutes.

DIVE ABORT PROCEDURES

6.4 The following were to be considered abort criteria:

a. major facility equipment failure;

b. medical problems (on the recommendation of the DMO in attendance); and

c. abandonment of the trials (on the recommendation of the RNTSO).

In the event of aborting the dive prior to 6 hours under pressure, the RN dive abort tables were to be used. After 6 hours under pressure, normal saturation decompression procedures were to be used.

DECOMPRESSION PHASE

6.5 Saturation decompression was conducted as per the table and instructions contained in Figures 17 and 18. This was a Non-Standard Decompression Schedule. Throughout the decompression phase, Doppler monitoring was conducted and several trials on the patient monitor were conducted. These are covered in more detail in the medical summary.

DIVE SUBJECTS

6.6 All subjects were volunteers and they were briefed by an independant medical officer prior to the dive. On completion of the briefing, a "Consent to Participation" form was completed. All subjects were qualified RN Saturation Divers. Six candidates were medically screened and trained for this dive, but only 4 subjects were pressurized. They were designated subjects A-D, with subject A acting as Team Leader throughout the dive.

The final selection of the 4 dive subjects was made just prior to the dive on the advice of the SOHM, RNTSO, and DOS. The 2 spare subjects were employed at DCIEM for the duration of SAT-DIVE 2/85.

WATCHES

6.7 Four watches were employed in a 3 watch system for SAT-DIVE 2/85 to allow watch variety and to program in rest days. One additional requirement however, was the necessity to maintain continuity in the day

FIGURE 18

DECOMPRESSION PROCEDURES

1. The decompression profile is was follows:

	Time to Travel 1 msw in min	Travel Rate msw/hr	Total Time (hr.)
360 - 100 msw	38	1.58	164.6
100 - 10 msw	60	1.00	254.6
10 - 0 msw	120	0.50	274.6
	Add 16 night stops of 6 hrs each:		96.0
	Total time of decompression		370.6

= 15.4 days

2. Gas levels were maintained during decompression as follows:

PO_2	0.5 bar	optimum
PCO_2	0.005 bar	maximum

As the chamber moved to shallower depths, the oxygen content of the chamber was monitored and increased to the levels required for each depth. At the shallow depths the oxygen content of the chamber was not allowed to exceed 21% by volume.

watch for trial stability purposes. Thus, for the compression and bottom phases, the same watch was programmed for the day watch while the remainder of the watches rotated through the other 2 watches. On completion of the bottom phase, the day watch commenced a rotation as well. The rotation was such that each watch only worked one day on each watch and this was to prove difficult for the individual watchkeepers to adjust to. A better arrangement would have been to have each watch stand 3 days in the same time period then rotate to the next period. The Hyperbaric Engineers stood a straight 1 in 3 watch while the 3 medical officers arranged a schedule between themselves to ensure a duty medical officer was available daily. For future dives it may be preferrable to have the engineers on twelve hour shifts or to augment their numbers. Greater advance notice of the shift schedule is also required for the civilian employees (minimum 2 weeks).

The following positions were manned continuously:

Dive Watch Officer
Chief Operator
Operator
Assistant Operator

As previously stated, the DWO of each watch was in charge of all activities related to the dive during his watch whether scientific, medical, or operational.

Watch change-over times were adjusted as necessary to accommodate the experiment schedule, meal times, etc.

The duty Hyperbaric Engineer (HE) was within the confines of DCIEM at all times. The duty DMO was required "on-site" for all equipment evaluations and at all other times immediately available by phone and within thirty minutes traveling time of DCIEM.

CHAMBER ATMOSPHERE PARAMETERS

6.8 The makeup of the hyperbaric atmosphere of the chamber complex was closely monitored at all times during the dive. The Sybron Taylor O_2 analyzer was referenced once daily against a gas analysis sample. The following parameters were set for the chamber.

a. pO_2

0.5 Bar for compression/decompression and 0.45 Bar on the bottom - with an extreme range of 0.25 - 0.6 Bar in exceptional circumstances. Chamber oxygen content was not allowed to exceed 21% by volume. The following were the set point

high and low limits and the alarm settings used for the O_2 control systems:

(1) **Compression/Decompression**

high alarm - 383 mmHg (0.51 Bar)
high limit - 375 mmHg (0.50 Bar)
low limit - 368 mmHg (0.49 Bar)
low alarm - 353 mmHg (0.47 Bar)

(2) **On the Bottom (360 msw)**

high alarm - 345 mmHg (0.46 Bar)
high limit - 338 mmHg (0.45 Bar)
low limit - 330 mmHg (0.44 Bar)
low alarm - 315 mmHg (0.42 Bar)

The chamber pO_2 was maintained at a maximum of 0.5 Bar during compression and for the first 6 hours at 360 msw. It is then reduced to a maximum of 0.45 Bar for the remainder of the bottom time. After completion of the last in-water test, the chamber pO_2 was maintained at 0.45 Bar for a further twenty-four hours before it was raised again to 0.5 Bar for the decompression phase. The pO_2 on the bottom was reduced to 0.45 Bar on the direction of the UK Ethics Committee. They felt that as the dive subjects were undergoing excursions on a mix with a pO_2 of 0.74 Bar (98/2), that the chamber pO_2 should be lower than the maximum limit of 0.5 Bar to allow recovery from any cumulative high pO_2 exposure. Once at 50 msw, the O_2 controllers were setup and tuned and throughout the dive they managed the O_2 makeup very effectively only requiring minor adjustment when compared to the Sybron Taylor analyzer which was used as the standard. One slight problem involved the controllers vernier settings. They were found to only be a rough guide and once the pO_2 was known, the verniers had to be adjusted to get the O_2 add/alarm control sequence to activate at the appropriate levels.

b. pCO_2

0.005 Bar with a maximum limit of 0.02 Bar in emergency only. The pCO_2 limit could be exceeded during diving operations provided it was for short durations only and that the level remains inside 1.5%.

NOTE: In general, canister breakthrough was considered approaching when the pCO_2 at ECL outlets reached one-half the pCO_2 level of the chamber, provided that the pCO_2 level in the chamber was at or near the limit.

c. **pN_2**

This was not allowed to exceed a partial pressure of .8 Bar at any time throughout the dive;

d. **Temperature**

24-34°C was the acceptable range with the dive start temperature 25°C. The governing factor was diver comfort and the temperatures ranged from 24-29°C over the course of the dive; and

e. **Humidity**

The normal range was to be 55-65% relative humidity with an extreme range of 50-80% in abnormal circumstances. Over the course of the dive, it was very difficult to maintain the normal range and even the extreme range was exceeded during showers despite any precautions taken.

CHAMBER ATMOSPHERE ANALYSIS

6.9 Gas samples of the chamber atmosphere were taken once daily from the LC, the TC, and the DC and analyzed for the presence of contaminants. A canister containing molecular sieve and charcoal was kept available but was not used. As the levels of N_2 were monitored and were not to exceed .8 Bar, extreme care in He flushing of the medical locks and sanitary tank prior to each pressurization was taken. A 2 minute flush was used for all lock movements except for food as this cooled the food too much. Over the course of the dive, several interesting things were discovered:

a. traces of nitrous oxide in the chamber led to the discovery of a contaminated O_2 bottle on the bank and thus, an oxygen pre-use gas analysis program was implemented;

b. the introduction of an ice chest into the chamber led to minute traces of freon 111 and 113 showing up with the only likely explanation being the ice itself;

c. the Sybron Taylor O_2 analyzer proved to be extremely accurate; and

d. on both the 100m and 360m dive when the fire suppression system was put back on-line the nitrogen content in the chamber atmosphere climbed. This was eventually traced to a crossover on the pressure tracking system.

Chamber CO_2 and humidity levels proved for a 1 week stretch to be running high and difficult to control during decompression. A number of different ECL cross-connect alignments were trialed and indications were that in the LC loop, canister #2 was not flowing correctly. It was also determined that insufficient moisture was remaining in the canister beds at times and this also contributed to the poor performance of the soda lime.

EMERGENCY AND BOTTOM BREATHING GAS MIXTURES

6.10 The following emergency and bottom breathing gas mixtures were brought on-line to the BIBS and the SMOC at the appropriate depths. These mixes gave a pO_2 within the recommended span of .4-1.2 Bars.

DEPTH	GAS MIXTURE
0- 40m	80/20 He/O_2
40- 80m	90/10 He/O_2
80-160m	93/7 He/O_2
160-190m	97/3 He/O_2
190-360m	98/2 He/O_2

The appropriate emergency gas mixture for the depth of the DRF was kept on "A" Manifold of the BIBS throughout the dive. They were checked with the O_2 analyzer when they are brought up to the manifold. Emergency gas mixtures were pressurized up to the chamber BIBS masks ready for immediate use by chamber subjects. A problem developed in the system at 120 msw as the chamber pressure was greater than the valve spring pressure on the overboard dump valve manifold and they leaked thus, necessitating the isolation of the overboard dumps at the hull isolation stop.

TREATMENT GAS MIXTURES

6.11 The following treatment gas mixtures were available for bringing on-line to the BIBS at the appropriate depth levels of the dive. These mixes gave a pO_2 within a span of 1.0 - 2.5 Bar:

DEPTH	GAS MIXTURE
0- 18m	100% O_2
19- 30m	40/60 He/O_2
31- 52m	60/40 He/O_2
53-115m	80/20 He/O_2
116-240m	90/10 He/O_2
240-330m	93/7 He/O_2
330-360m	97/3 He/O_2

During decompression the appropriate treatment gas mixtures were brought on-line to the BIBS Control Console for pressurizing "B" Manifold.

BIBS MASK

6.12 A series of unmanned evaluations of the Scott BIBS Mask were conducted using the LC and a breathing machine before SAT-DIVE 2/85. These tests conclusively proved that the Scott Masks could not cope with a demand greater than resting subjects at any depth beyond 50 msw. A set-up using the AGA Divator Mask was then trialed and proved to be adequate for moderate workloads at depth. A set of 8 of these masks were assembled (4 with comms) and they were taken into the chamber by the subjects for the dive. This work will be reported separately (see Section 1 Table 1).

FIRE PROTECTION

6.13 The DRF Fire Suppression sub-system was isolated beyond 80 msw on descent and remained isolated until the DRF returned to the 80 msw level on ascent. As the hand spray nozzles leaked from the start of compression, they were isolated at the hull stops at 50 msw.

LOGS AND RECORDS

6.14 The following logs, records, and procedures were maintained at the control room:

a. **Tape and Video Recording**

SAT-DIVE 2/85 was recorded on the Dictaphone Dictalog 4000 (voice activated VOX mode). In addition, all experiments were video taped on the Panasonic time lapse video recorder. Medical checks were kept confidential and therefore, were not monitored or recorded;

b. Dive Protocol Master Copy;

c. Master Log;

d. Chamber Atmosphere Data Log and Graphs;

e. Environmental Control Data Log;

f. Medical Lock Log;

g. **Systems/Sub-system Checklists**

Checklists were used by DRF operating personnel bringing

systems/sub-systems on-line, changing the status of a system or shutting down any such system. For the frequently used systems such as potable water and sanitary system, a master checklist was posted on-site;

h. Machinery Log; and

j. Emergency Procedures.

DIVE CHAMBER WATER STATUS

6.15 The chamber water was initially set at 4°C. The ECU cooling loop was generally brought on-line 3 hours in advance of the in-water test time. Once at 360m it became necessary to set water start temperature at 3°C in order to stay within the 4°$\pm$ °C range for the main system test when the hot water suit was in use for up to 3 hours.

PRE-DIVE CLEANING

6.16 The following pre-dive cleaning routine was followed:

a. all parts of the chamber were scrubbed with ivory soap and then wiped over with Betadyne solution (1:2000);

b. bedding and mattress covers were washed and rinsed in Ivory Liquid (1:100);

c. all diving suits and undersuits were washed in Ivory liquid (1:100). They were also washed in the same solution on completion of the dive before being dried and stowed. Oral-nasals and helmet liners were also washed with the same solution; and

d. no working boots or shoes or dirty working clothing were worn inside the diving system, particularly during the preparation for the dive.

CLEANING DURING SATURATION DIVES

6.17 Throughout the saturation dive the following cleaning routines were followed:

a. heads, ablution facilities and their surrounding areas were washed down with Ivory Liquid soap daily;

b. all deck and working surfaces (tables, handlocks, and seats) were wiped over daily with Ivory liquid soap and chamber walls and bulkheads were similarly cleaned every third day;

c. bedding was changed at least every twenty-four hours;

d. clothing was changed daily; and

e. as far as was practicable, all diving suits and undersuits were washed daily in Ivory Liquid soap. This was done outside the chamber and dry equipment locked in for each diver.

POST-DIVE CLEANING

6.18 On completion of the dive, the chambers were emptied and liberally washed down with Ivory Liquid and then Staphex. In addition, all suits, bedding, etc., were washed as previously described.

EXTERNAL EAR PROPHYLAXIS

6.19 In the morning and evening all subjects carried out ear prophylaxis. The subjects also conducted ear prophylaxis:

a. twenty-four hours pre-dive;

b. wet and standby divers after every wetpot entry; and

c. after showering.

In any case, all subjects were required to do a minimum of 3 applications per day using VOSOL OTIC solution. The solution was kept in each external ear canal for 5 minutes.

DAILY WEIGHTS

6.20 Subject body weights to the nearest 0.1 Kg were taken daily. 3 of the subjects lost weight in the range of 1-3 Kg.

FUNGAL INFECTION PROPHYLAXIS

6.21 At the morning and evening ear prophylaxis times, all subjects applied Tinactin solution to the web spaces between their toes from his personal bottle (to be clearly marked). No fungal infection was noticed throughout the dive.

SATURATION DECOMPRESSION SICKNESS THERAPY

6.22 Although it did not occur, treatment for saturation decompression sickness would have been initiated as shown in the flow diagrams (Figures 19 and 20). After compression, high oxygen partial pressure mixtures in the range of 1.5-2.5 Bars could be administered up to 6 X 20 minute periods with 5 minute intervals.

EQUIPMENT TRIAL - DETAILS

6.23 The equipment tested during the main trial was:

a.	The Gasmizer	- 50, 120, 250, 320, 360m;
b.	Heliox 500	- 360m;
c.	NRV Suit	- 50, 120, 250, 320, 360m;
d.	FCO Suit (Norsk Hydro)	- 50, 120, 250, 320, 360m;
e.	Divematics Suit (Norsk Hydro)	- 360m;
f.	Diver Monitor	- 360m; and
g.	Patient Monitor	- during decompression from 360m

6.24 The details of the test specifications and the applicable abort criteria are contained in Annex A.

6.25 With the exception of the Divematics suit, all trial objectives were completed successfully. Of the twenty-seven scheduled dive serials, 8 were aborted, either totally or partially; seventeen were completely successful and 2 were cancelled as unnecessary. The data collected during the training dive covered 2 of the aborted dives, the remainder being covered by repetitive evolutions in other experiments, except for the 2 Divematics suit aborts which were total failures. Therefore, by making maximum use of dive serial time, it was possible to retrieve all the information lost due to aborts and even cancel 2 scheduled trials as no longer required. This enabled decompression to start twenty-four hours early, which was fortuitous due to the very heavy post-dive test requirements and experiments the subjects were required to complete in the limited time frame post-dive.

6.26 The causes of aborts were singly or a combination of:

a. scientific equipment failure, the pedal ergometer, the diver scientific or medical monitoring equipment;

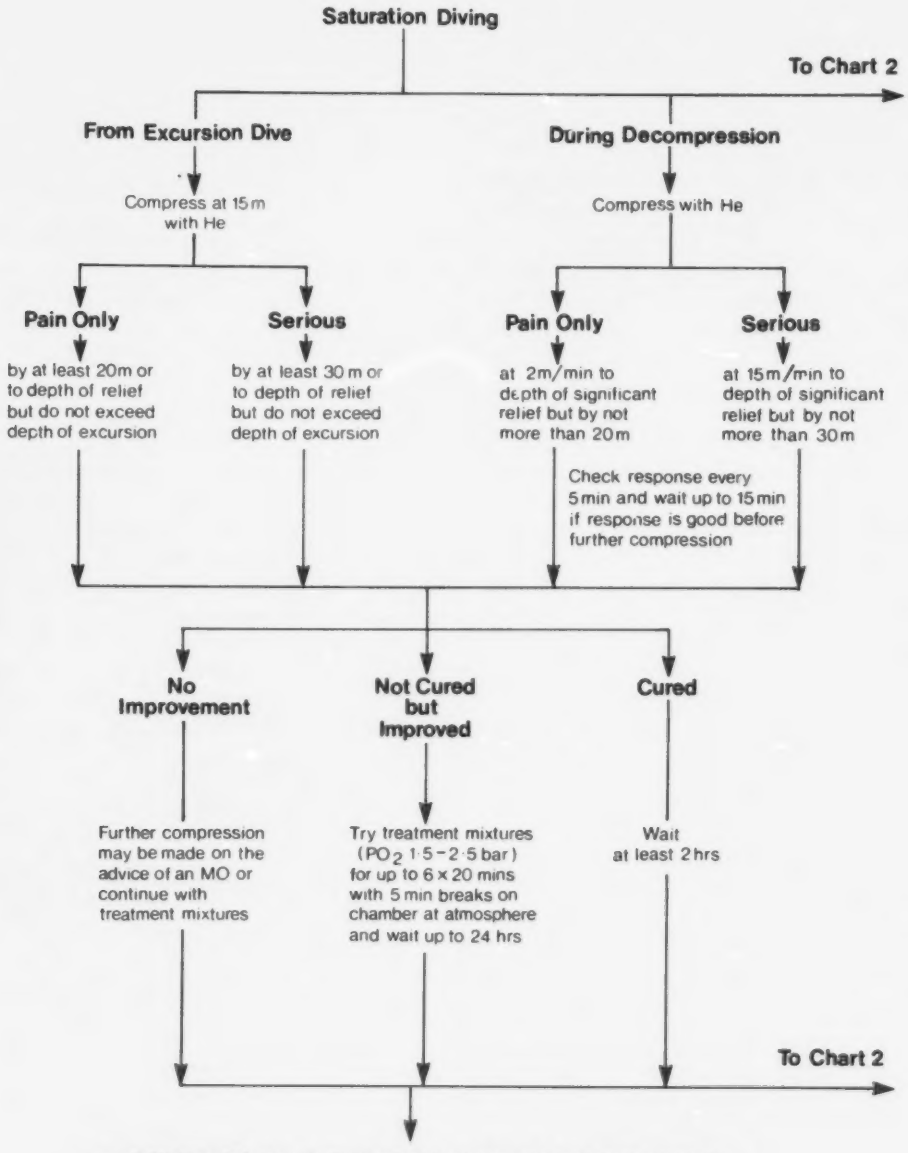
b. diver unwell or unfit to continue;

c. trial equipment failure, problems with the Gasmizer or the Divematics suit. The detailed breakdown is as shown in Figure 21.

Figure 19

Treatment of Decompression Sickness

(Chart 1)


Saturation Diving
To Chart 2
From Excursion Dive
During Decompression
Compress at 15m with He
Compress with He
Pain Only
Serious
Pain Only
Serious
by at least 20m or to depth of relief but do not exceed depth of excursion
by at least 30m or to depth of relief but do not exceed depth of excursion
at 2m/min to depth of significant relief but by not more than 20m
at 15m/min to depth of significant relief but by not more than 30m
Check response every 5min and wait up to 15min if response is good before further compression
No Improvement
Not Cured but Improved
Cured
Further compression may be made on the advice of an MO or continue with treatment mixtures
Try treatment mixtures (PO_2 1·5–2·5 bar) for up to 6 x 20 mins with 5 min breaks on chamber at atmosphere and wait up to 24 hrs
Wait at least 2 hrs
To Chart 2

DECOMPRESS ON SATURATION SCHEDULE GIVEN BELOW
but without the initial upward excursion

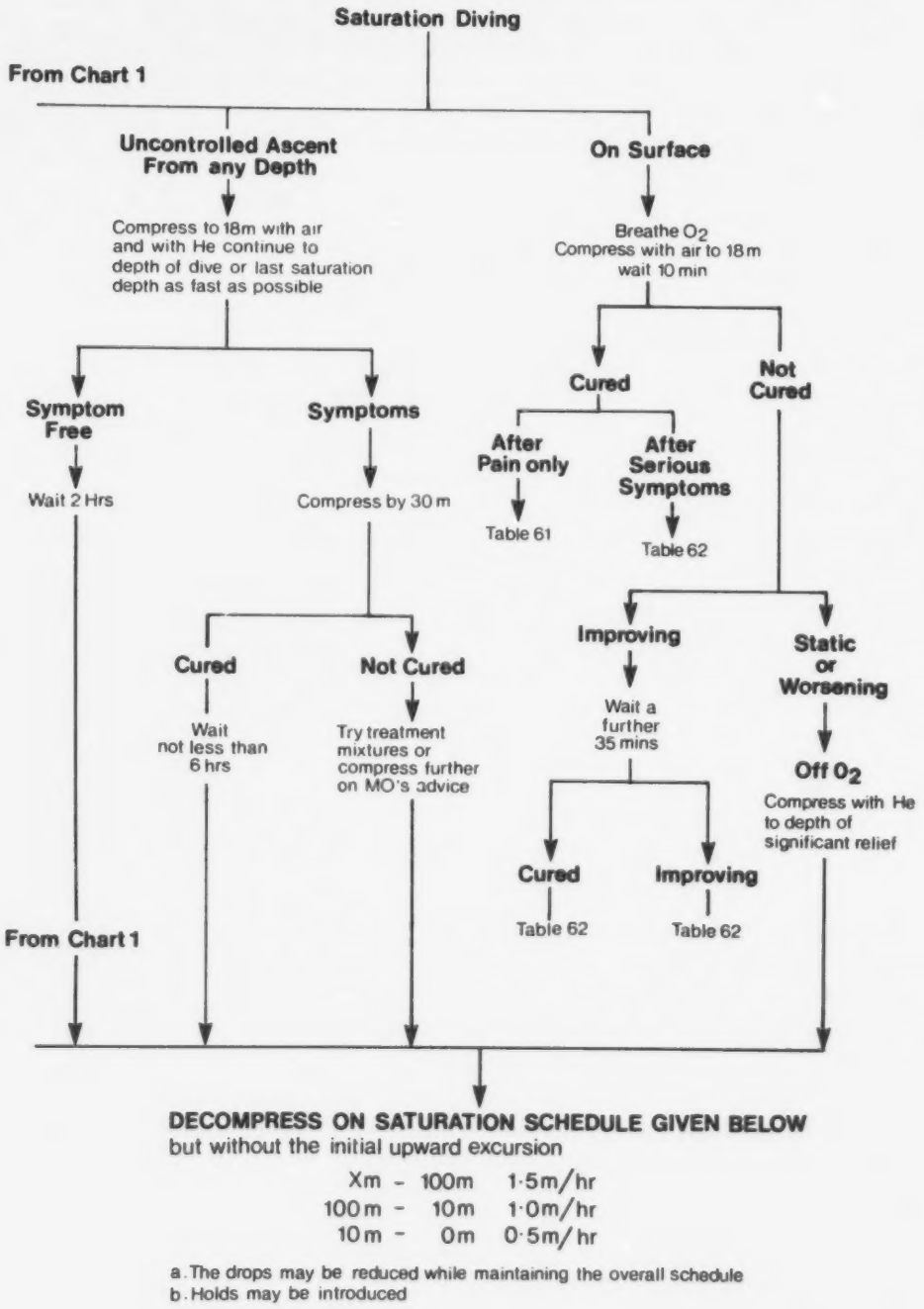
Xm	-	100m	1·5m/hr
100m	-	10m	1·0m/hr
10m	-	0m	0·5m/hr

a. The drops may be reduced while maintaining the overall schedule.
b. Holds may be introduced

Figure 20

Treatment of Decompression Sickness

(Chart 2)



a. The drops may be reduced while maintaining the overall schedule
b. Holds may be introduced

MEDICAL OFFICERS DIVE SUMMARY

6.27 Compression and Decompression Profiles

The maximum depth for SAT-DIVE 1/85 was 100m which was well within the limits of normal RN Saturation Diving. As it was also a training dive, standard RN procedures for compression and decompression were used. SAT-DIVE 2/85 was an experimental dive and its maximum depth of 360m meant that routine RN tables could not be used without extrapolation. In addition, NUTEC proposed the testing of a compression profile for this depth with relation to HPNS. The main objective of the dive however, was to conduct equipment trials and as such the mandate of the Medical Working Group was to keep the divers fit for work. The eventual compression schedule incorporated RN rates to 250m and the experimental Norwegian profile from there to 360m. In keeping with the Norwegian proposals, a pO_2 of 0.5 Bar was to be maintained throughout the majority of the dive. The decompression used continuous rates described in the supplement to BR1750A for experimental diving with the addition of 6 hour night stops. Overall,the rates were more conservative than those used in standard RN saturation and decompression.

6.28 Equipment Trials

Many of the experiments called for physical exertion of various grades. As different forms of exercise were being used from bike tests to finning it was decided to monitor equivalent workload by heart rate, a parameter which had good correlation on the surface. An abort criterion was set at 85% of maximum predicted heart rate. In practise a combination of pO_2 and depth lead to a resting bradycardia in the divers up to twenty beats per minute. This made the application of the abort criterion and judgement of workload more difficult than anticipated. As it was unknown if maximum heart rate decreases with depth, on several cases the Medical Officer stopped a diver from increasing his workload at heart rates less than the calculated surface 85% maximum. During the 360m dive, a rest period of 2 to 3 minutes was found to be necessary between workloads to allow heart rate stabilization and the return of the subjects sense of well being.

During monitoring an ECG waveform could be obtained from working divers and on occasions, apparent PVC's were seen on the oscilloscope at 360m. As the equipment was only designed to monitor heart rate, the significance of the changes could not be determined. More convincing was the observation of T wave inversion at rest in 2 divers in water at 360m.

Delta P changes sufficient to cause abort were found only in the emergency trials simulating Gasmizer failure.

FIGURE 21

DIVE TRIAL BREAKDOWN

DEPTH	EQUIPMENT	REMARKS
360	Gasmizer/NRV-2 Main System Trial	Completed.
360	Gasmizer/FCO Excursion Trial	Aborted. Diver unwell. (Sufficient data collected to complete trial objective).
360	Gasmizer/NRV-2 Emergency Trial	Aborted. Scientific equipment failure, rectal temperature and Δ p.
360	Gasmizer/FCO Main System Test	Brought forward. Completed.
360	Gasmizer/FCO Excursion Trial	Postponed from 02 Jul. Completed. Retrieved data lost from previous trial at 360 msw.
360	Heliox 18 (UF500) Trial	Completed.
360	Gasmizer/Divematics Main System Trial	Aborted. Diver unwell.
360	Gasmizer/Divematics Main System Trial	Aborted. Hot water suit failure.
360	Divematics Suit	Completed. Modified trial with immersion to neck for data collection.
360	Gasmizer/FCO Excursion Trial	Cancelled. No longer required.
360	Gasmizer/NRV-2 with Diver Monitor	Brought forward. Completed.
360	Makeup Serials	Cancelled. No longer required.
360 to 75	Patient Monitoring trial during decompression	Completed.

FIGURE 21 (con't)

DIVE TRIAL BREAKDOWN

DEPTH	EQUIPMENT	REMARKS
360	Gasmizer/NRV-2 Main System Trial	Completed.
360	Gasmizer/FCO Excursion Trial	Aborted. Diver unwell. (Sufficient data collected to complete trial objective).
360	Gasmizer/NRV-2 Emergency Trial	Aborted. Scientific equipment failure, rectal temperature and △ p.
360	Gasmizer/FCO Main System Test	Brought forward. Completed.
360	Gasmizer/FCO Excursion Trial	Postponed from 02 Jul. Completed. Retrieved data lost from previous trial at 360 msw.
360	Heliox 18 (UF500) Trial	Completed.
360	Gasmizer/Divematics Main System Trial	Aborted. Diver unwell.
360	Gasmizer/Divematics Main System Trial	Aborted. Hot water suit failure.
360	Divematics Suit	Completed. Modified trial with immersion to neck for data collection.
360	Gasmizer/FCO Excursion Trial	Cancelled. No longer required.
360	Gasmizer/NRV-2 with Diver Monitor	Brought forward. Completed.
360	Makeup Serials	Cancelled. No longer required.
360 to 75	Patient Monitoring trial during decompression	Completed.

Temperature regulation in excurted saturation divers is a complex subject. Measurements of gas temperature were made by a fast acting thermister skin temperature, measured at 6 sites and core temperature by a rectal probe. Various other temperature readings were available to give indication of hot water supply at different points.

Skin and core temperatures were never sufficiently elevated or depressed to cause abort by the criteria used. The Divematics suit caused subjective overheating and skin reddening during its trials.

Exhaled gas temperature was difficult to determine from the information available. On gas heating shut off at 100m, the inspired temperature rapidly fell and the diver requested reconnection within a minute. In neither case was the core temperature effected.

The most common problem with diver heating arose due to equipment design. If the diver was subjectively comfortable at rest, the gas heating would be insufficient for heavy work. Conversely, if acceptable for heavy work, he would be too hot at rest if the water bypass was not used. Beyond 100 msw thermal balance is difficult to maintain using current heating methods. Therefore, these dives should be supported by thermal monitoring.

Divers often showed a 0.5°C elevation of core temperature which occurred before entering the water. As has been found previously, a diver's subjective feeling of being comfortable did not reflect his gradual diminuation or increase in skin or core temperature.

Elevated inspired or expired CO_2 did not reach abort limits during experiments.

Occasional equipment failures deprived the Medical Officer of parameters which had stated limits. In all but 1 experiment the Medical Officer judged that there was sufficient remaining information to allow safe continuation.

6.29 HPNS and Arthralgia during Compression and Bottom Time

Testing for HPNS was carried out by representatives from NUTEC during SAT-DIVE 2/85 and this is the subject of a separate report. Mild HPNS was detected in the divers by 250m. Compression arthralgia was reported by 3 of the divers from 320m to 360m.

6.30 General Health

The divers remained remarkably healthy and motivated throughout the dives. The fact that there were no skin or ear problems can, in part, be attributed to good preventive medicine.

Buffered Acetic Acid drops (VOSOL) were used for ear prophylaxis at least 3 times a day. This preparation was well accepted by the divers. It showed no tendency to crystallization and contains a skin lubricant (propylene glycol diacetate). Tinactin solution was used twice daily in the web spaces between the toes. Washing was with Gamophen soap. On completion of SAT-DIVE 2/85, 1 of the divers who suffers from mild acne had noticeable improvement in his condition.

The divers demonstrated no weight change during SAT-DIVE 1/85. However, during SAT-DIVE 2/85, there was up to 6% weight loss by the end of the bottom phase, especially in the harder working divers. There was gradual weight recovery during decompression. Weight measurement was performed daily before excursions and the observed weight losses were unlikely to reflect transient fluid loss but more a result of exercise and loss of taste sensation. The situation would probably have been worse if great attention had not been paid to the diver's diet.

One diver reported abdominal pain during the bottom phase. A computer was used to assist in diagnosis based on the structured history and examination performed by one of his colleagues. The computer diagnosis of dyspepsia reinforced the DMO's opinion and was thus found extremely useful in this situation of difficult communication. Blood was taken from the patient by another subject on 2 occasions. The first sample was decompressed over 6 minutes and subsequently lost due to bubbling over. The second was decompressed over 12 minutes, showed no bubbling and was successfully analyzed.

During the 360m experiments, 2 of the divers reported a "marzipan" taste to the bottom mix which was intermittent and unpredictable. No contaminant was found on gas analysis and the cause, whether due to HPNS, suggestion or some other reason remains open to speculation.

To investigate any pulmonary oxygen toxicity arising from the use of a pO_2 of 0.5 Bar during both dives, full lung function was performed as a baseline after each dive. No decrement in vital capacity was discovered after either dive. Similarly, no symptoms or signs of respiratory disease were noted.

6.31 Decompression

No major tests were performed during decompression and for the majority of the time the divers ate, slept, and watched films. Resting heart rate was monitored during decompression and a gradual increase was observed. During the deeper part of the profile, the divers experienced an uncomfortable sensation of continuous middle ear equalization. The night stops gave welcome relief as did changing from continuous bleed to moving every twenty minutes.

Doppler monitoring was performed twice daily during decompression on both dives. In SAT-DIVE 1/85, Doppler scores remained at zero throughout. In SAT-DIVE 2/85, however, from 270m to 100m, there was a gradual increase in the number of divers affected and bubble scores (to a moderate level). After the rate reduction at 100m from 1.5 metres/hour to 1.0 metres/hour the bubble scores diminished rapidly and were zero by 80m. One of the divers experienced uncomfortable skin itching between 240m and 120m which he associated with "off gasing". Doppler monitoring performed after 5 hours of stop at 127m showed that the divers were bubbling at the same rate as before the stop.

6.32 Post-Dive Flying Restrictions

It was initially considered that the RN minimum of forty-eight hours would be sufficient, however, after reconsidering the depth and severity of the dive, a question was referred back to the Medical Working Group. They decided that seventy-two hours would be prudent.

ANNEX A
to Section 6
Page 1 of 4

EQUIPMENT TEST SPECIFICATIONS

1. The following equipment tests were conducted during SAT-DIVE 2/85. The details of each test are contained in the Enclosures as shown:

Enclosure 1 - GSOL Gasmizer System Test Requirements

Enclosure 2 - Heliox 18B (Ultraflow 500) Test Requirements

Enclosure 3 - Divematics Closed Circuit Hot Water Suit Test Requirements

Enclosure 4 - FCO Open Circuit Hot Water Suit Test Requirments

Enclosure 5 - NGL Diver Monitor Test Requirements

Enclosure 6 - NGL Patient Monitor Test Requirements

Enclosure 7 - HPNS Test Requirements

2. For the equipments test, any or all of the following parameters were monitored with applicable abort criteria as shown:

a. **ECG**

Any sign of myocardial ischemia;

b. **Heart Rate**

Exceeding 85% of individuals predicted maximum (220-Age Formula);

c. **Inspired Gas Temperature**

In excess of 40°C for more than thirty seconds. In excess of 5 minutes at 6°C;

NOTE: A diver reporting any degree of copious bronchial mucous secretion was grounds for abort of the experiment in itself.

d. **Inspired Gas Analysis**

(1) if CO_2 exceeded 3% SEV (23 mmHg); and
(2) pO_2 outside .25-2.0 Bar.

e. **End Tidal Analysis**

If CO_2 exceeded 85 mmHg for more than 5 consecutive breaths.

f. **Core Temperature (Rectal)**

A fall of 1°C or a rise of 2°C from the pre-experiment baseline.

g. **Skin Temperature**

A fall to 10°C or a rise to 42°C at any of the monitoring sites listed in para 4(d).

h. **HPNS**

If present to any significant degree for twenty-four hours and not improving. (DMO may consider a second twenty-four hour wait before aborting).

j. **Subject Request**

To be considered by DMO and RNTSO. Appropriate recommendations to be made to WO.

k. **Subject Health**

If in the opinion of the DMO the subject's health will be endangered;

m. **Oral-nasal**

. . p - $\pm$ 3.5 kPA relative to the demand valve.

n. **Hot Water Flow to Suit**

Failure - monitored diver subpara (c), (f), and (g) apply;
- unmonitored diver - abort test.

p. **Hot Water Temperature at Splitter Block**

As per subpara (n).

q. **Communications**

A serious failure of chamber communications.

In the event of a failure of any of the monitoring equipment, the DMO could recommend the continuation of the experiment provided he was satisfied with the other available data.

3. For all equipment evaluations in the water, the following positions were manned by the subjects:

a. Red Diver;
b. Standby Diver;
c. Dive Leader; and
d. Tender (as required).

4. In order to be able to apply the Abort Criteria parameters, the following monitoring equipments were used by the subjects as required:

a. dry 3 lead ECG monitor;

b. dry twelve lead ECG monitor;

c. wet 3 lead ECG monitor;

d. skin temperature recording disks, 6 places (hand, forearm, chest, thigh, calf, and foot);

e. Rectal probe; and

f. EEG monitor.

5. In addition, all helmets were outfitted for:

a. breath-by-breath CO_2 and end tidal CO_2;
b. inspired/expired gas temperature; and
c. oral-nasal .. p.

6. At each stop during the descent and on the bottom, EEG monitoring and neuro-psychological testing was conducted during the acclimatization periods. In chamber Doppler monitoring was also conducted on the decompression phase to assist in determining the efficiency of decompression.

7. Divers were also requested to provide subjective information as during the specific tests.

ENCLOSURE 1
to Annex A
Page 1 of 4

GSOL GASMIZER SYSTEM

1. The GSOL Gasmizer System consisted of the following equipments:

   a. Gasmizer Helinaut 500 helmet (Figure 22);
   b. divers hot water suit;
   c. integration components;
   d. system support van; and
   e. mobile test facility (MTF) containing:

      (1) second diver simulator chamber (to be fitted with a GSOL helmet and utilized as the second diver depth on all tests) (Figures 23 and 24);

      (2) breathing machine (BM). Used in conjunction to simulate the second diver (Figure 25); and

      (3) unmanned test bell (Figure 26).

2. The following tests were programmed for the GSOL Gasmizer systems over the course of the dive in accordance with the following schedule:

50m	Test A	- Excursion Trial
120m	Test A	- Excursion Trial
	Test B	- Dry Diver Bike Test
	Test C	- Main System Performance Check
	Test D	- Emergency System Trial
250m	Test A	- Excursion Trial
	Test B	- Dry Diver Bike Test
320m	Test A	- Excursion Trial
	Test B	- Dry Diver Bike Test
360m	Test A	- Excursion Trial (upward only)
	Test B	- Dry Diver Bike Trial
	Test C	- Main System Performance Check
	Test D	- Emergency System Trial

FIGURE 22

GSOL GASMIZER HELINAUT 500 HELMET

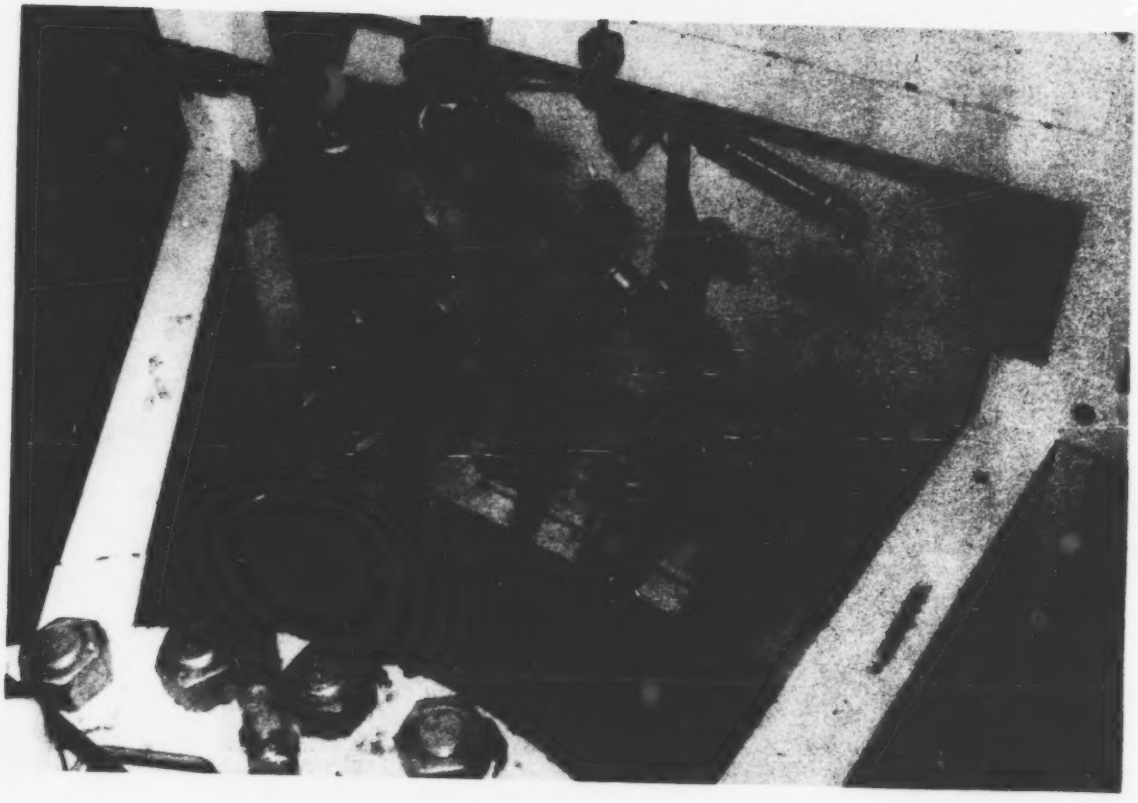


FIGURE 23

SECOND DIVER SIMULATOR CHAMBER EXTERIOR FACE

FIGURE 24

SECOND DIVER SIMULATOR CHAMBER FITTED WITH MANIKIN HEAD INSIDE

FIGURE 25

MTF BREATHING MACHINE

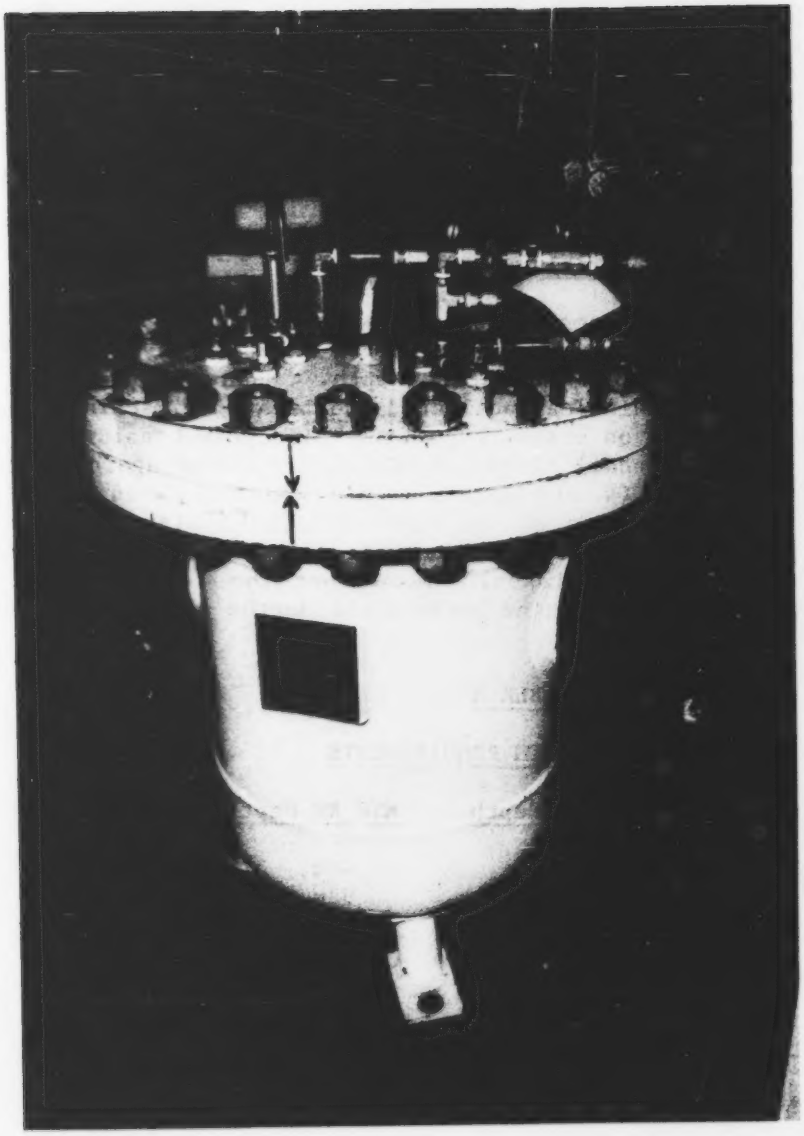


FIGURE 26

UNMANNED TEST BELL

3. **DIVE TESTS DETAILS**

a. **Test A - Excursion Trial**

For each test the diver entered the water at the depth shown, the bell was set to the required depth and the MTF breathing machine was placed at the start depth. When all positions were set, the Trials Team activated the breathing machine and started the diver on his work cycle. This cycle consisted of twelve minutes pedalling the vertical ergometer against an incremented load (4 min light, 4 min moderate, and 4 min heavy). On completion of the work cycle, the diver had a 5 minute rest. After the rest the work cycle was repeated and a second rest period taken. Throughout the test, the MTF moved the breathing machine between the depths shown in Table 3.

TABLE 3

TEST A - DEPTH REQUIREMENTS

Dive Depth	Bell Depth	MTF BM Depths
50m	50m	46m, 67m
120m	100m	92m, 120m
250m	230m	220m, 260m
320m	300m	290m, 330m
360m	360m	350m

b. **Test B - Dry Diver Ergometer Trial**

This test was done to assess the subject's ability to work in the increased gas density and it was completed by all subjects prior to entering the water for any subsequent tests.

The subject dressed in PT gear was fitted with the leads for the twelve lead hardwired ECG monitors. On completion, he took up a position on the dry ergometer in the LC and dialed on the first workload. When all positions were set, the Trials Team started the work cycle. This cycle consisted of twelve minutes of pedalling against an incremented workload (4 min light, 4 min moderate, and 4 min heavy). After each 4 min period, an assistant was instructed to dial up the next workload while the subject continued to pedal. Throughout

the work cycle, the subjects heart rate was monitored using the appropriate cutoff (85% HR max). On completion of the work cycle, the subject remained in place while an ECG strip was taken on the twelve lead machine;

c. **Test C - Main System Test**

This test consisted of 5 separate parts and involved an in-water excursion of about 3 hours/subject. For these tests, Red Diver, the Bell and the MTF breathing machine were all at the same depth. The test consisted of:

(1) **Part 1**

Nut puzzle (Figure 27) - twelve bolts were removed, fitted back into place and tightened again. Each segment was timed.

(2) **Part 2**

Vertical ergometer - twelve minutes pedalling the vertical bike against an incremented load (4 min light, 4 min moderate, and 4 min heavy). This was followed by twenty minutes of work against a constant moderate load after a 5 minute rest period.

(3) **Part 3**

Valve assembly (Figure 28) - a system of pipework and valves was broken down and reassembled in a fixed sequence. After reassembly, the system was pressurized and leak tested. Each section of the task was timed.

(4) **Part 4**

Swim bar - twelve minutes swimming at different rates (4 min light, 4 min moderate, and 4 min heavy). This was followed by twenty minutes swimming at a constant moderate rate after a 5 min rest period.

(5) **Part 5**

Umbilical cut - the diver cut a piece off a sample length of umbilical.

Throughout this series of tests, the MTF breathing machine was working constantly.

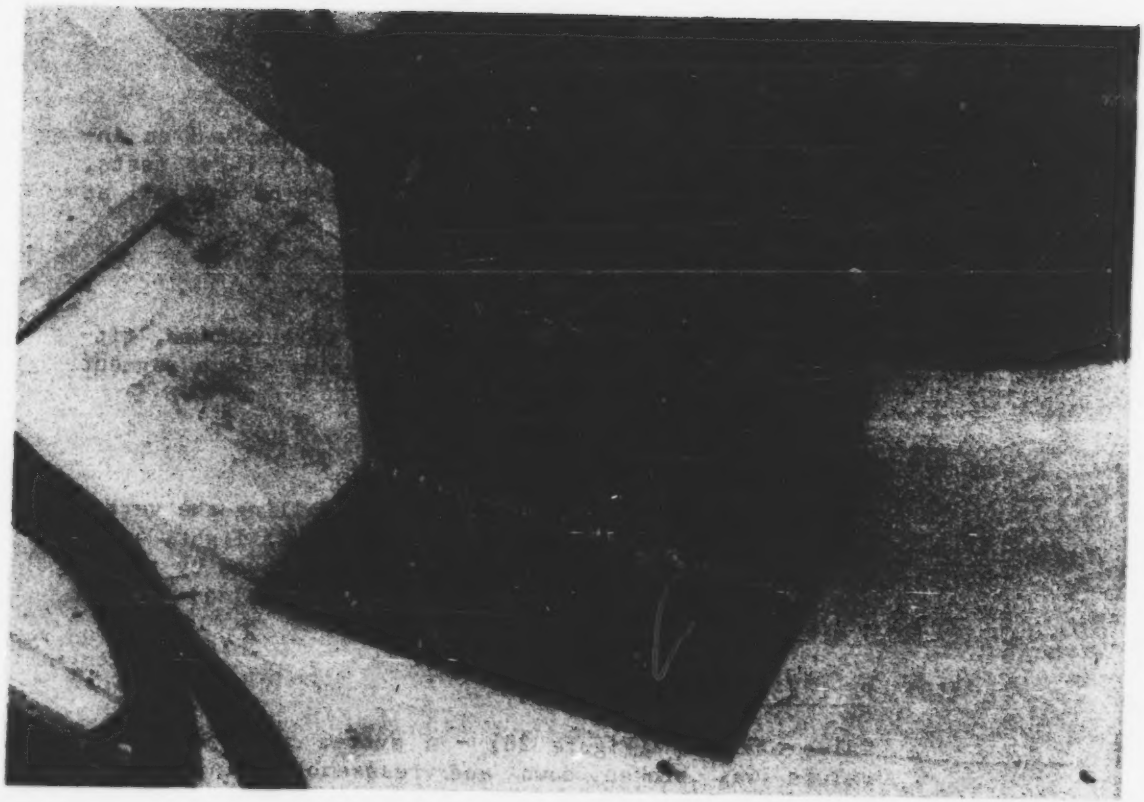


FIGURE 27

NUT PUZZLE

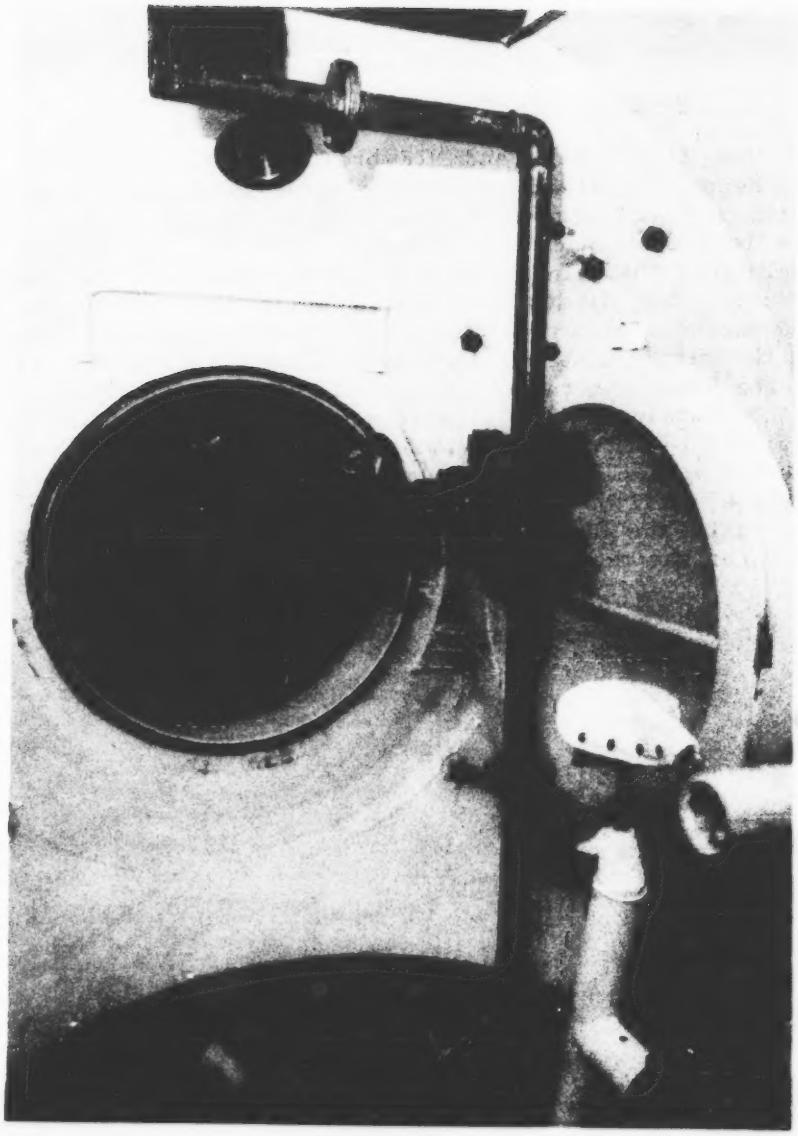


FIGURE 28

VALVE PUZZLE

d. **Test D - Emergency System Trial**

With the diver, Bell and MTF breathing machine all at the same depth, the diver entered the water and commenced working on the vertical ergometer at a constant moderate rate. Once this is established, a measurement of Δ p was taken. On completion, the main gas supply was switched off, Δ p again measured, the diver then rested while the gas supply was reconnected. Once reconnected, the diver recommenced working and the return line was then switched off, Δ p was measured, the Diver instructed to open his diverter valve and Δ p measured again and the line reconnected. Finally, hot water supply to the diver was switched off. The diver continued to work on open circuit and time was taken from water supply stoppage until a 3°C drop in expired gas temperature was reached or the diver could not continue. At this point the hot water was restored and the test was terminated.

ENCLOSURE 2
to Annex A
Page 1 of 1

HELIOX 18B (ULTRAFLOW 500)

TEST REQUIREMENTS

1. The Heliox 18B outfit consisted of the following equipment:

   a. Heliox 18B (Ultraflow 500) band mask (Figure 29);
   b. Diver's hot water suit; and
   c. Integration components.

2. The following tests were conducted on this equipment at 360m:

   a. **System Performance Test**

      This test consisted of 2 parts:

      (1) **Part 1**

      Vertical ergometer - twelve minutes pedalling the vertical bike against an incremented load (4 min light, 4 min moderate, and 4 min heavy). This was followed by twenty minutes of work against a constant moderate load after a 5 minute rest period; and

      (2) **Part 2**

      Swim bar - twelve minutes swimming at different rates (4 min light, 4 min moderate, and 4 min heavy). This was followed by twenty minutes swimming at a constant moderate rate after a 5 minute rest period.

   b. **Diver Rescue Task**

      The diver was required to dress from an "immediate notice" state and enter the wetpot to effect a rescue of a second diver stationed at the far end of the wetpot. The time taken to complete dressing and effect the rescue to the "sitting up, helmet off" position was taken.

FIGURE 29

HELIOX 18B (ULTRAFLOW 500) BAND MASK

ENCLOSURE 3
to Annex A
Page 1 of 2

DIVEMATICS CLOSED CIRCUIT HOT WATER SUIT

TEST REQUIREMENTS

1. The Divematics Closed Circuit Hot Water Suit system consisted of the following equipment:

   a. the Submersible Diver's Heating Unit (SDHU);

   b. the Surface Control Unit;

   c. Bell Manifold System;

   d. integration components and 8m umbilical; and

   e. Divematics Closed Circuit Tube Inner Suits and overgarment suits (Figures 30, 31, 32, and 33).

2. The following tests were conducted on this equipment:

   a. Pre-dive system checkout;
   b. Test C - Main System Performance Test (360m); and
   c. Test D - Emergency System Trial (360m).

3. **Pre-Dive System Checkout**

The pre-dive system checkout consisted of filling the SDHU with water on completion of system installation. This water stood in the unit for twenty-four hours to ensure complete saturation of the water bearing. On completion, the unit was run initially for about 1 minute with the vent open to remove any trapped air. After this precaution, a suit was connected to the manifold umbilical and a system operation check completed. This test was also repeated on arrival at 360msw.

4. **Test C - Main System Performance Check (360m)**

This test was identical to that used to test the GSOL equipment and the details are contained in Enclosure 1 to Annex A para 3(c).

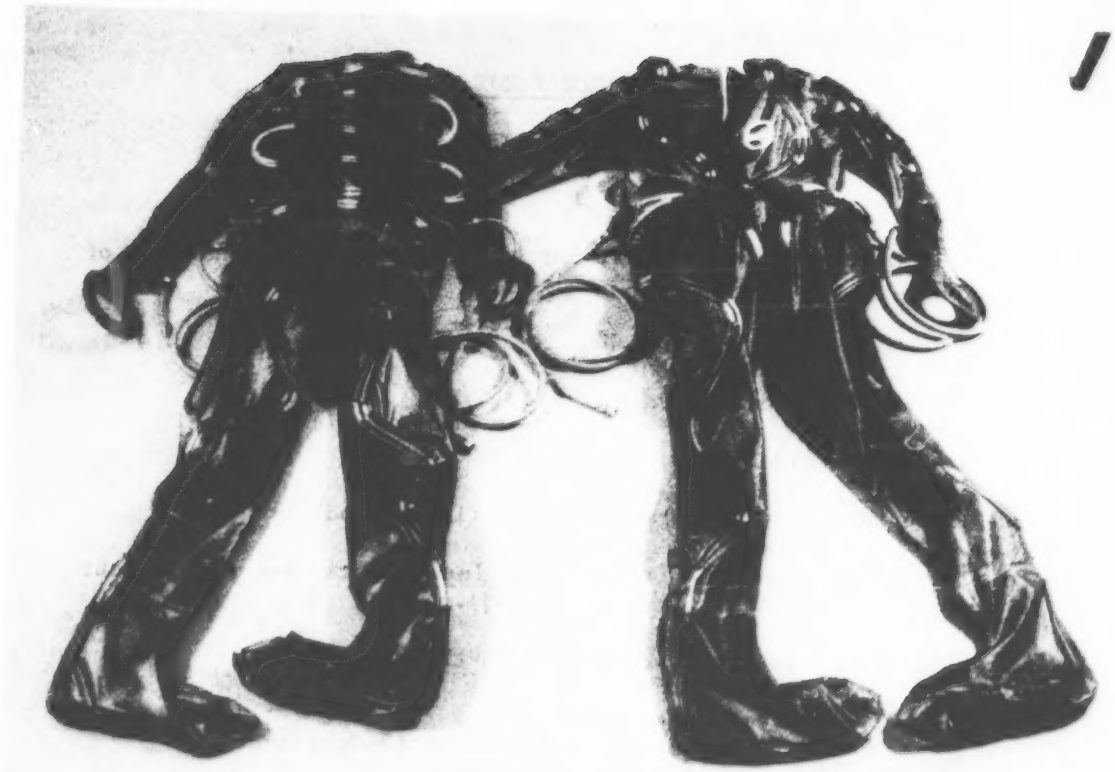


FIGURE 30

DIVEMATICS CLOSED CIRCUIT TUBE INNER SUIT

FIGURE 31

DIVEMATICS THINSOLITE OVER GARMENT

FIGURE 32

DIVEMATICS DRY SUIT

FIGURE 33

DRESSING IN THE DIVEMATICS SUIT

5. **Divematics Emergency System Trial (360m)**

In this test, only the hot water supply for the suit was turned off leaving the gas heating shroud supplied with hot water. The diver continued to work and time was taken from water stoppage until any of the 6 skin temperature measurements read 15°C or the diver requested to abort. At this point, the hot water was restored and the test terminated.

ENCLOSURE 4
to Annex A
Page 1 of 1

FCO OPEN CIRCUIT HOT WATER SUIT

TEST REQUIREMENTS

1. The FCO Open-Circuit Hot Water Suit is similar in all respects to the diver's Hot Water Suit as per BR 8196. It was being tested as a possible alternative to the in-service suit (Figure 34).

2. The following tests were conducted using this suit over the course of the dive in accordance with the following schedule:

50m	Test A	-	Excursion Trial
120m	Test A	-	Excursion Trial
250m	Test A	-	Excursion Trial
320m	Test A	-	Excursion Trial
360m	Test C	-	Main System Performance Check
	Test D	-	Emergency System Trial

3. **Test A - Excursion Trial**

This test was identical to that used to test the GSOL equipment and the details are contained in Enclosure 1 to Annex A para 3(a).

4. **Test C - Main System Performance Check (360m)**

This test was identical to that used to test the GSOL equipment and the details are contained in Enclosure 1 to Annex A para 3(c).

5. **Test D - Emergency System Trial**

This test was identical to that used to test the GSOL equipment and the details are contained in Enclosure 1 to Annex A para 3(d).

FIGURE 34

FINN CHRISTIAN OLSEN (FCO) SUIT

ENCLOSURE 5
to Annex A
Page 1 of 1

NORMALAIR GARRETT DIVER MONITORING EQUIPMENT

TEST REQUIREMENTS

1. The NGL Diver Monitoring System consisted of the following equipment:

a. thoracic belt assembly including 3 electrodes and a suit temperature thermister (Figure 35);

b. twenty-way cable connecting thoracic belt to multiplexer;

c. multiplexer mounted on diver's back;

d. multiplexer calibrator;

e. bent tube mounted with thermistor;

f. hot water suit modified with "elephant trunk" and block thermistor (Figure 36);

g. 4 and 6 track pen recorder;

h. storage oscilliscope; and

j. digital volt meter.

2. The following test was conducted by Red Diver on this system at 360m:

Function Test

Prior to 1 of the GSOL Test C Main System Performance Checks, Red Diver doned this monitoring equipment in addition to that required for the GSOL test. Throughout the test, data was obtained from this system and compared with the known monitoring data to allow an assessment of the systems capabilities. The data from this system was not used to determine diver abort and failure of this system was not to cause the abort of the GSOL test.

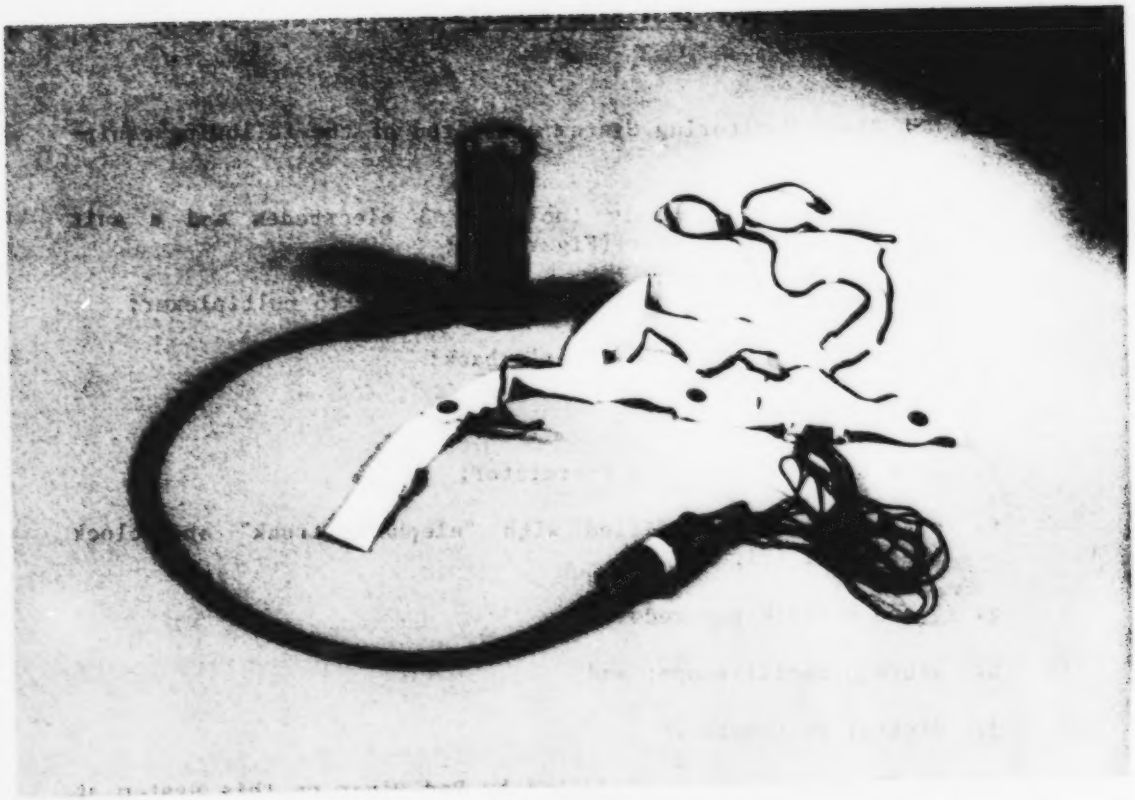


FIGURE 35

NGL DIVER MONITOR THORACIC BELT ASSEMBLY

FIGURE 36

DRESSING IN THE DIVER MONITOR EQUIPMENT USING "ELEPHANTS TRUNK" MODIFIED SUIT

ENCLOSURE 6
to Annex A
Page 1 of 1

NORMALAIR GARRETT PATIENT MONITOR

TEST REQUIREMENTS

1. The NGL Patient Monitoring System consisted of the following equipment:

   a. patient sensor and lead assemblies (Figure 37);

   b. multiplexers (Figure 38);

   c. impedance tester;

   d. multiplexers calibrator;

   e. multiplexer connected by twisted pair cable through penetrators to demultiplexer rack assembly equipment;

   f. 4 and 6 track per recorder;

   g. storage oscilliscope; and

   h. digital volt meter.

2. The following function test was conducted during the decompression phase of the dive:

   a. the subject dressed with the leads for the ECG, EEG, EOG core and skin temperatures. Once dressed, readings were taken with the subject stationary and then mobile.

FIGURE 37

NGL PATIENT MONITOR SENSOR ASSEMBLY

FIGURE 38

NCL PATIENT MONITOR MULTIPLEXER

ENCLOSURE 7
to Annex A
Page 1 of 1

HIGH PRESSURE NEUROLOGICAL SYNDROME

TEST REQUIREMENTS

1. The following battery of tests were conducted during the compression and bottom phase of the dive to assist in the detection of HPNS:

a. **Compression Battery**

(1) EEG;
(2) intentional tremor;
(3) postural tremor;
(4) finger tapping;
(5) hand grip strength; and
(6) visomotor and cognitive functioning.

b. **Performance Measuring**

(1) finger, manual dexterity;
(2) visual reaction;
(3) digit stan;
(4) arm, wrist speed; and
(5) operational testing.

c. symptom questionnaire.

2. These tests were conducted at the following times during the dive:

a. during compression, all tests were completed after arrival at each deep compression stop (250m and 320m) and the compression battery repeated 1 hour before leaving each stop. In addition, while enroute to the 250m stop, a series of tests were conducted from 150-180 msw.

b. on reaching the bottom, all the tests were done and then repeated 6 and twelve hours later; and

c. daily during the bottom phase.